SwRI's Contribution to the Analyzer of Space Plasmas and Energetic Atoms (ASPERA-3) Experiment on ESA's Mars Express

Presented By: Rudy A. Frahm

Present Status of Mars Express

All systems and experiments operational.

In orbit around Mars since December 2003.

Launch was June 2003.

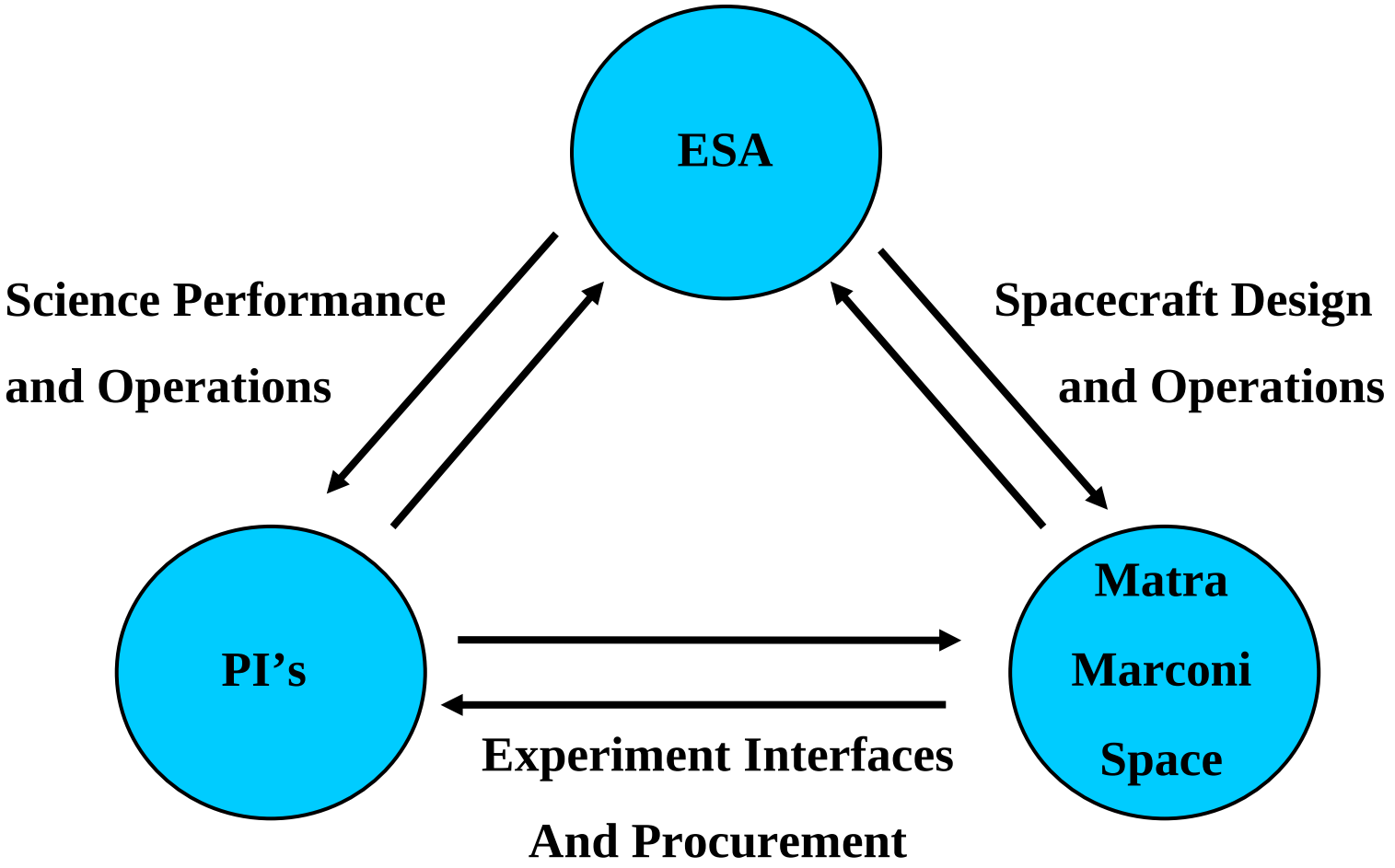
The Mission Objectives

Mars Express is a mission of comparative planetology. It makes observations of the surface, atmosphere, surface - atmosphere and atmosphere - interplanetary medium interactions.

Mars Express is an imaging mission and performs:

- **global high resolution imaging (photogeology)**
- **global high resolution IR imaging (mineralogical mapping)**
- **atmosphere composition monitoring (IR spectroscopy)**
- **global atmospheric UV imaging (mapping of atmospheric composition and circulation)**
- **subsurface remote sensing (radar)**
- **Global energetic and neutral atom imaging (plasma and neutral gas distributions)**

MEX Management Implementation



The MEX Payload

Instrument	Name	Principal Investigators	Institute
ASPERA	Energetic Neutral Atoms Analyser	R. Lundin	Swedish Institute of Space Physics, Kiruna, Sweden
HRSC	High Resolution Stereo Colour Imager	G. Neukum	Institut für Planetener-kundung, Berlin, Germany
OMEGA	IR Mapping Spectrometer	J. P. Bibring	Institut d'Astrophysique Spatiale, Orsay, France
PFS	Atmospheric Fourier Spectrometer	V. Formisano	Istituto Fisica Spazio Interplanetario, Rome, Italy
RSE	Radio Science Experiment	M. Paetzold	University of Cologne, Cologne, Germany
SPICAM	UV Atmospheric Spectrometer	J. L. Bertaux	Serviced'Aeronomy, Verrieres-le-Buisson, France
SSRA	Sub-surface Sounding Radar / Altimeter	G. Picardi	University of Rome, Rome, Italy
Beagle 2	Lander	C. Pillinger	Open University, Milton Keynes, UK

ASPERA Team

R. Lundin, S. Barabash, H. Andersson,	
A. Grigoriev, M. Holmström, M. Yamauchi	***IRF, Kiruna, Sweden***
K. Asamura *JAXA / ISAS,*	***Sagamichara, Japan***
P. Bochsler, P. Wurz	***UBe, Switzerland***
A. Coates, D.R.Linder, D.O.Kataria	***MSSL, UK***
C. C. Curtis, K. C. Hsieh, B. R. Sandel	***UA, Tucson, USA***
R. Frahm, J. Sharber, D. Winningham	***SwRI, San Antonio, USA***
M. Grande, M. Carter, D. H. Reading	***RAL, Oxfordshire, UK***
H. Koskinen, E. Kallio, P. Riihela, T. Säles	***FMI, Helsinki, Finland***
J. Kozyra	***SPRL /U. of Michigan, Ann Arbor, USA***
N. Krupp, S. Livi, J. Woch	***MPAe, Katlenburg-Lindau, Germany***
J. Luhmann	***SSL /U. of California in Berkeley, USA***
S. McKenna-Lawlor	***STIL, Ireland***
S. Orsini, R. Cerulli-Irelli, A. Mura, A. Milillo	***IFSI, Rome, Italy***
E. Roelof, D. Williams	***APL /JHU, Laurel, USA***
J.-A. Sauvaud, A. Fedorov, J.-J. Thocaven	***CESR, Toulouse, France***

ASPERA-3 Components

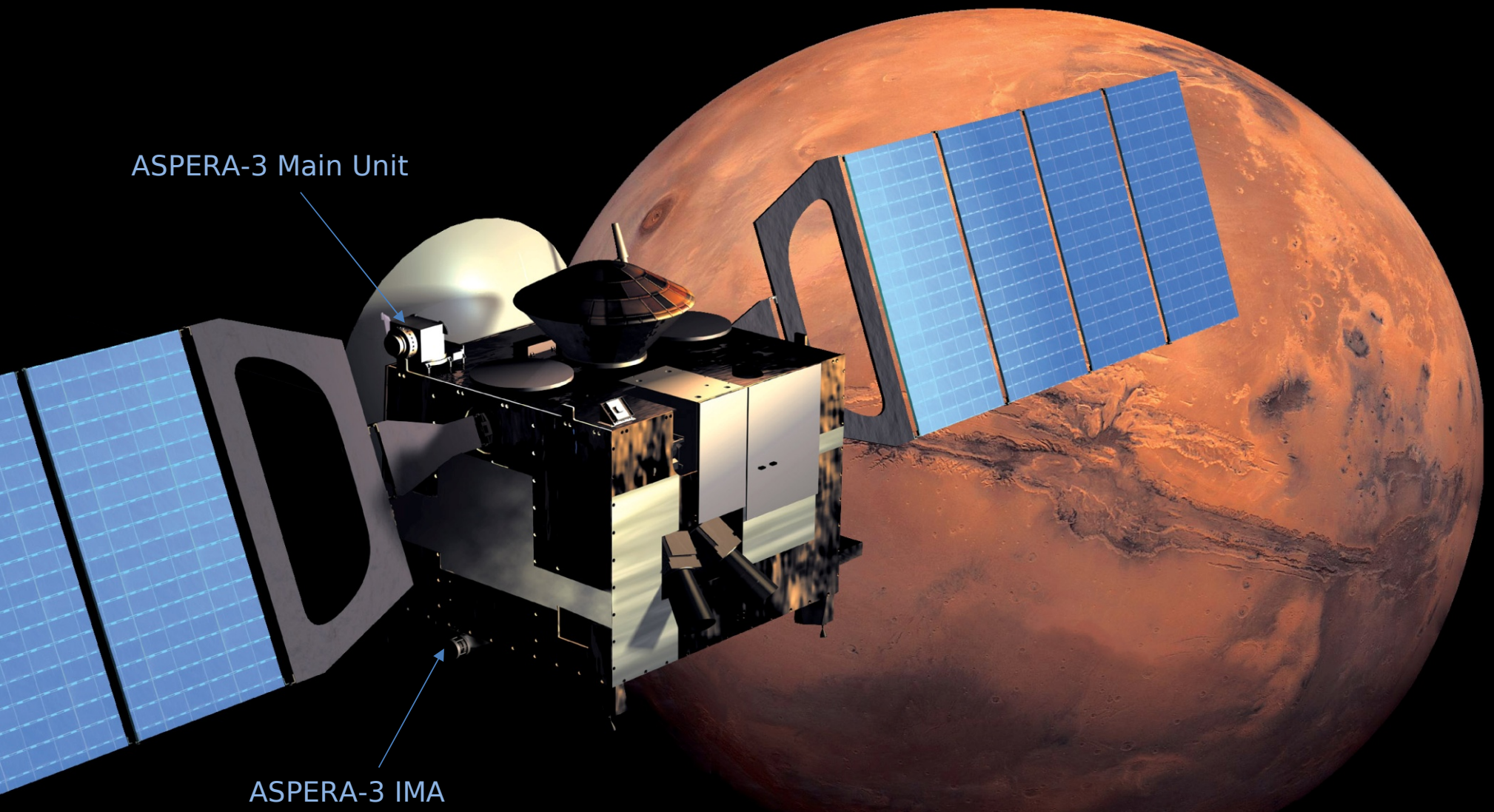
IMA Unit:

Ion Mass Analyzer (IMA)
Data Processing Unit (DPU)

Main Unit:

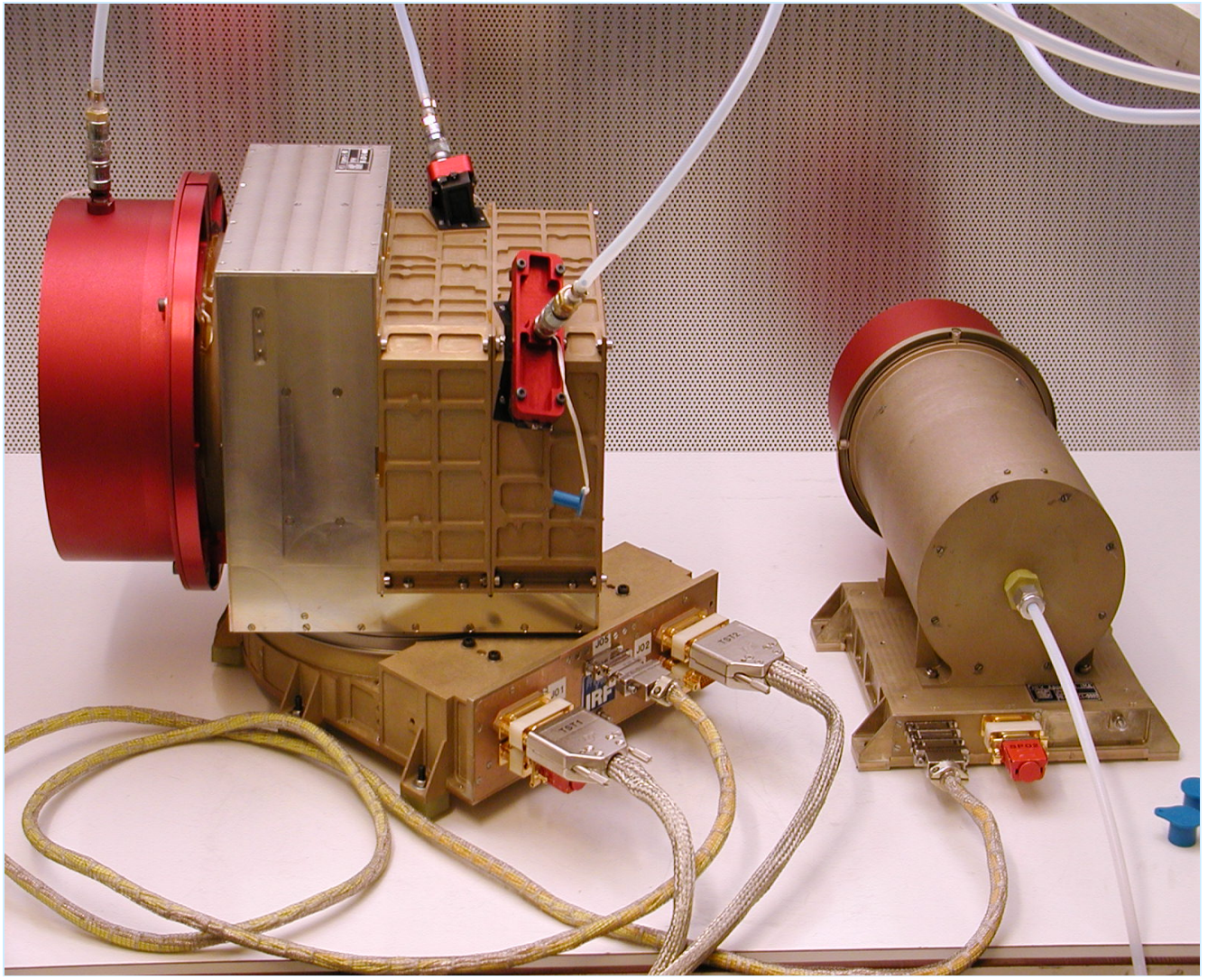
Neutral Particle Detector (NPD)
Neutral Particle Imager (NPI)
NPI Solar Sensors (SS)
Electron Spectrometer (ELS)
Main Unit DPU (MU)
Scanner

Mars Express in orbit around MARS

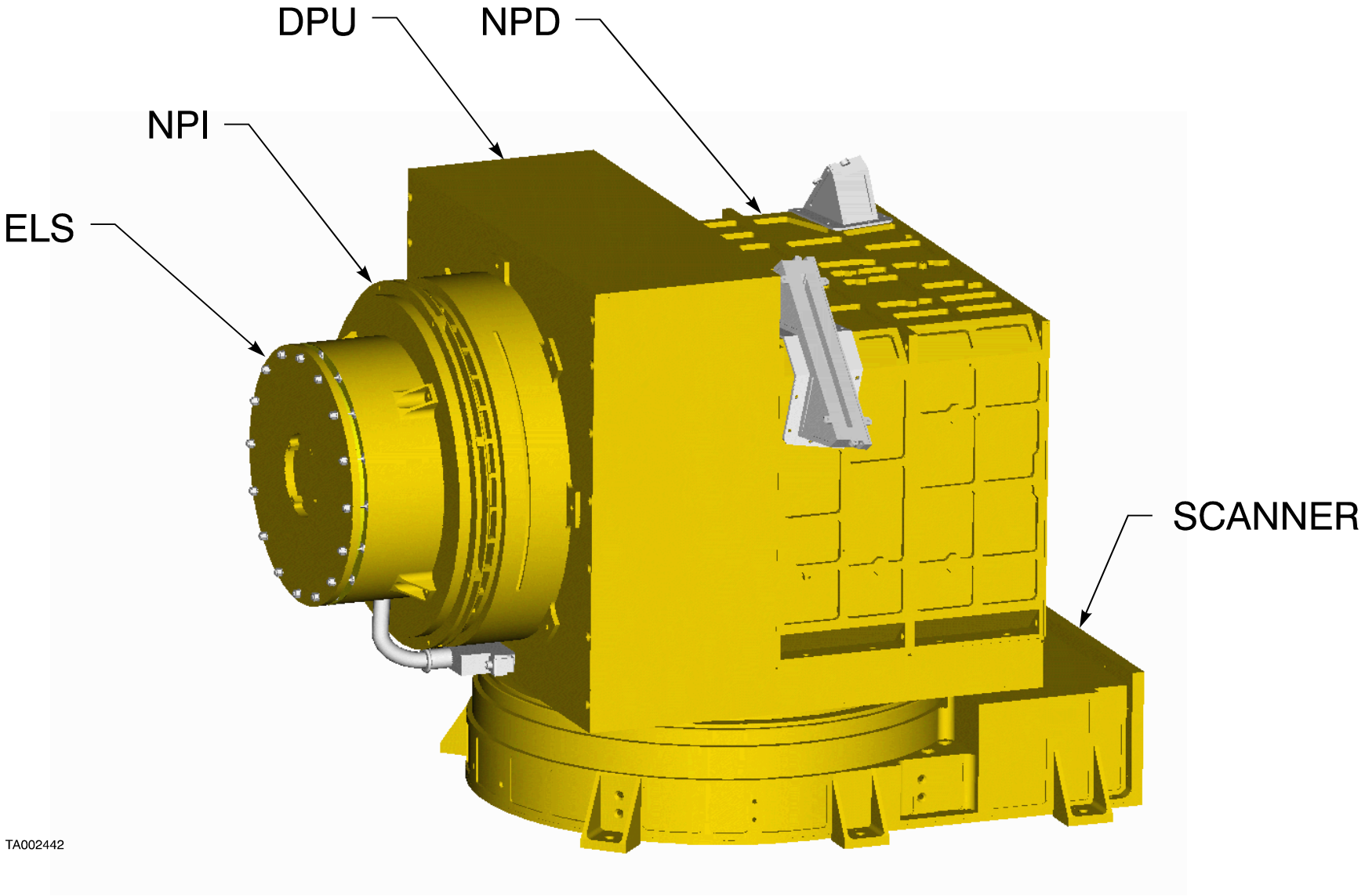


Credits: ESA – Illustration by Medialabi, ID number: SEMBHY0P4HD

ASPERA-3 Ready for Flight



ASPERA-3
SCANNER INSTRUMENTATION



SwRI Areas of Involvement in ASPERA-3

SwRI was and is Involved in three areas which include: Hardware, Software, and Science.

All three areas of SwRI involvement began at the proposal stage and participated in the project simultaneously.

Hardware

John Scherrer - PM pre-launch

Tom Adamietz[3], Jack Alexander[3], Tony Alonzo[1], Albert Anaglia[1], Irene Arevalos, Willie Barth, Kim Barclay, Tom Booker[4], John Brune[3], Pat Casey[3], Jason Castillo[1], Carolin Chadwell[1], Pat Chenault, Greg Dirks, Joe Esquivel, Connie Garza[1], Robert Garza, George Geleta[1,8], Pat Gonzales, Chris Grandjean[1], Dennis Guerrero, Rita Guerrero, Brian Gupta[3], Bob Harbaugh, Marc Johnson, Sisoulith (Lit) Ksor[1,8], Joe Langle[1], Walter Lockhart[5], Larry McCullough[3], Walter McGinnis[3], Bill McLaren, Tom Mayces, Ernie Mayfield[1], Holly Mayfield[1], Richard Menchaca, Annette Nordenstam[1], Greg Palacios, Norm Pelletier, Kristian Persson, Susan Pope, Adrian Ramirez, Robert Rendon, Jeff Roese, Syrrel Rogillio[3], John Rudzki[1], James Sanders, Richard Sanders[1,8], Kelly Smith, Toby Stecklein[1], Norma Swaka, Tony Swaka, Linda (Bjork) Theis[1], Carlos Urdiales.

[1]No longer at SwRI, [2]Converted to TA, [3]Retired from SwRI, [4]Now in Div 18, [5]Private Contractor, [6]Div 16, [7]Now at ITC, [8]Deceased

SwRI Hardware Involvement

SwRI was involved in two of the four instruments comprising the ASPERA-3 experiment: IMA and ELS.

SwRI was charged with improving the IMA anode and providing an ELS instrument.

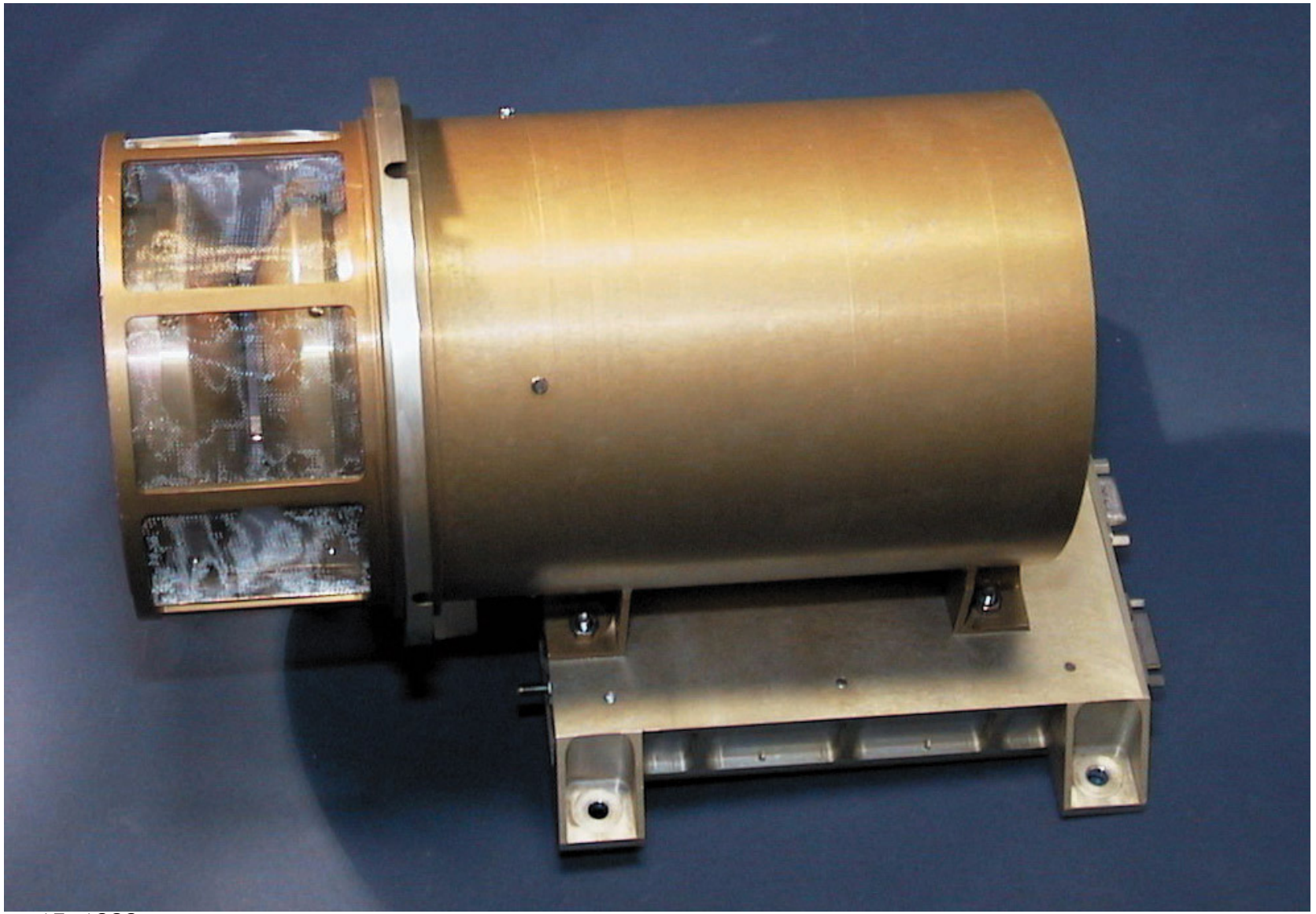
SwRI IMA Involvement

1) SwRI improved the IMA anode design and functionality,
2) Built the IMA anode and 2 flight spare anodes,
3) tested the IMA anode.

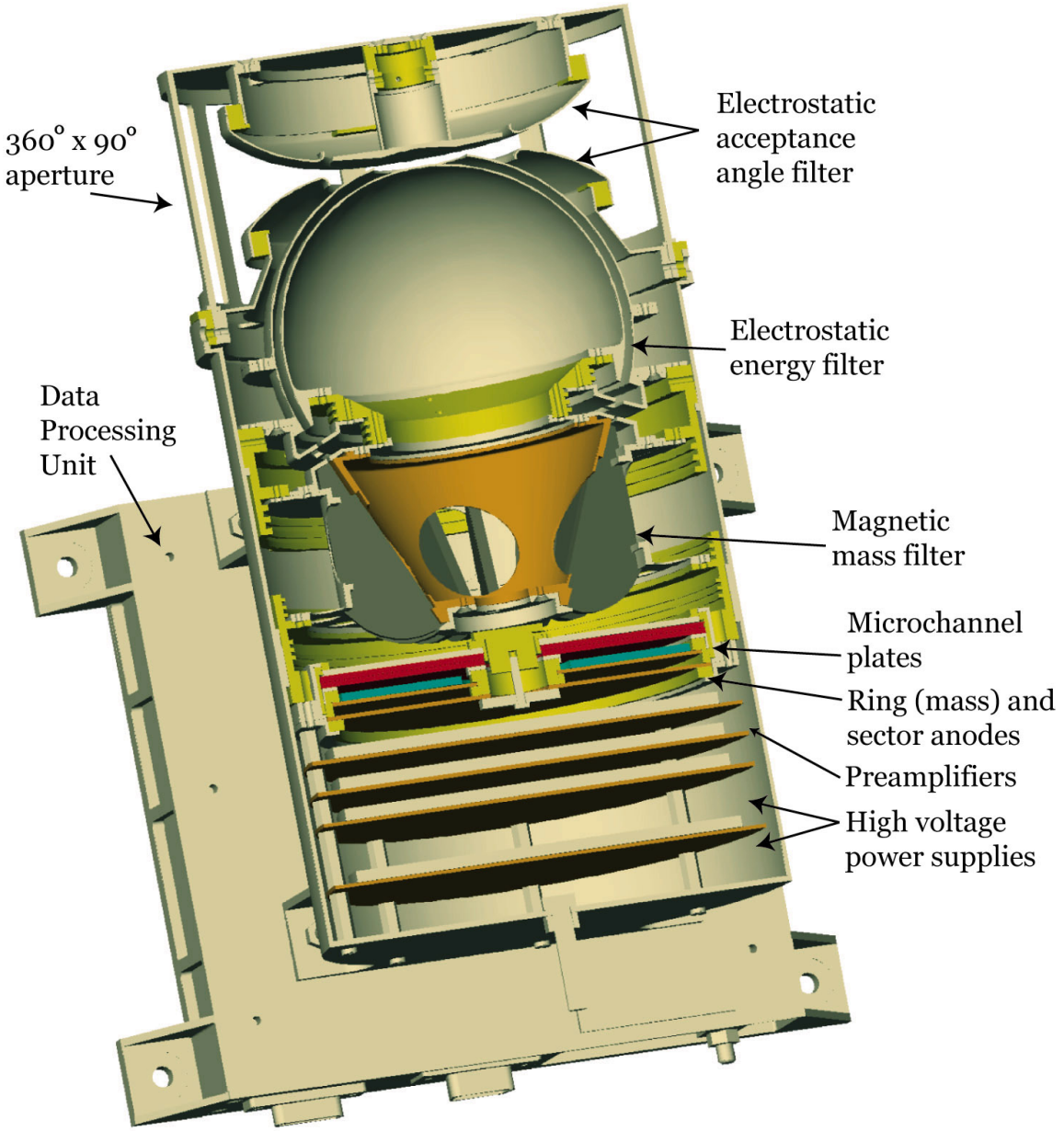
remainder of IMA constructed at IRF and CESR

Note: 1 flight spare anode is in Ion Composition Analyzer instrument on Rosetta

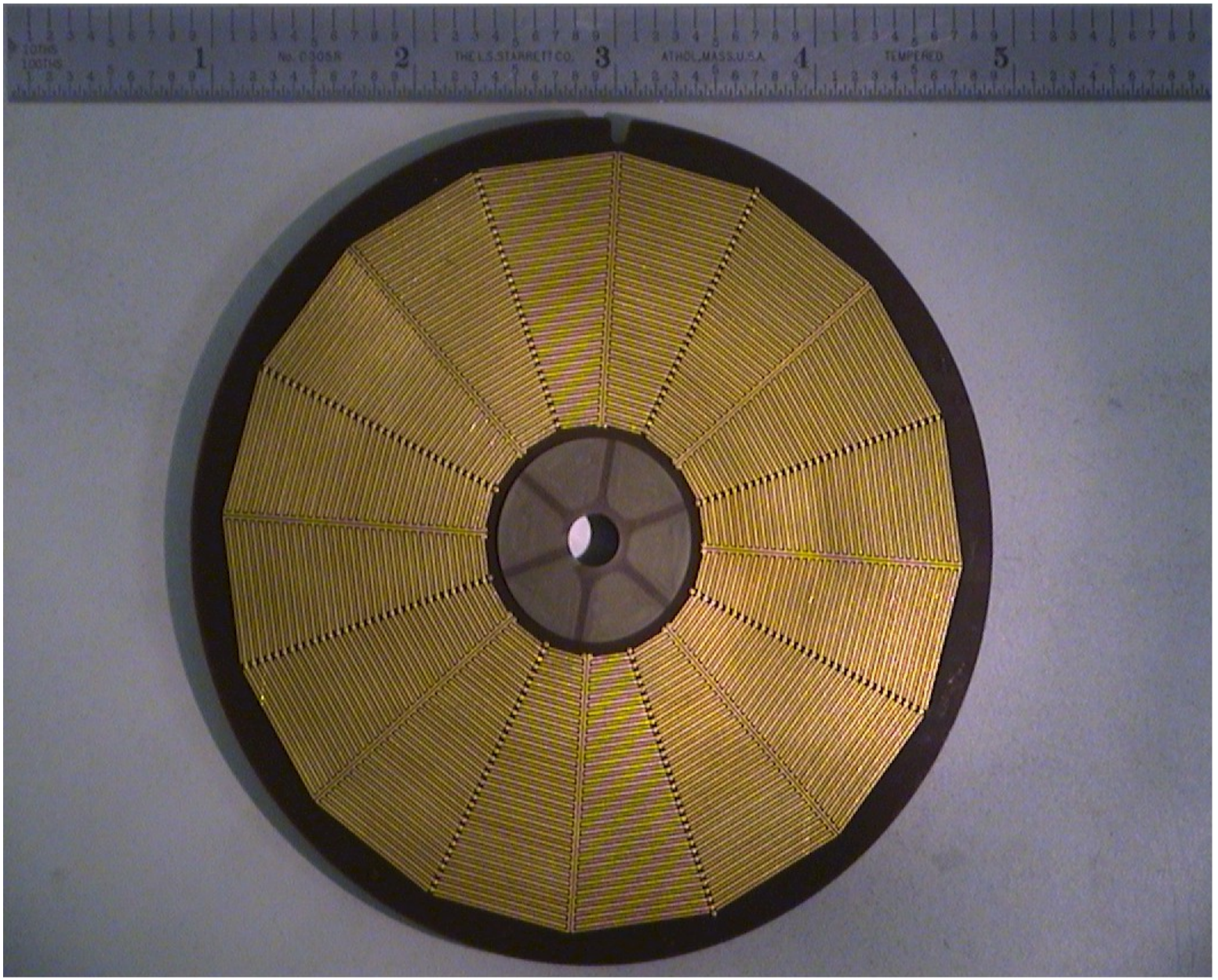
ASPERA-3 IMA



Cross Section of IMA

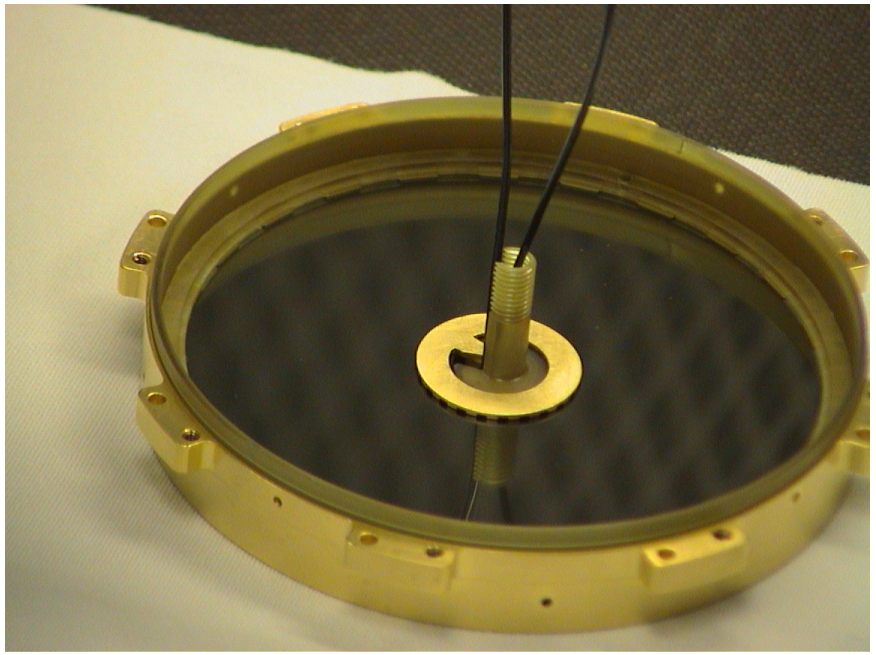


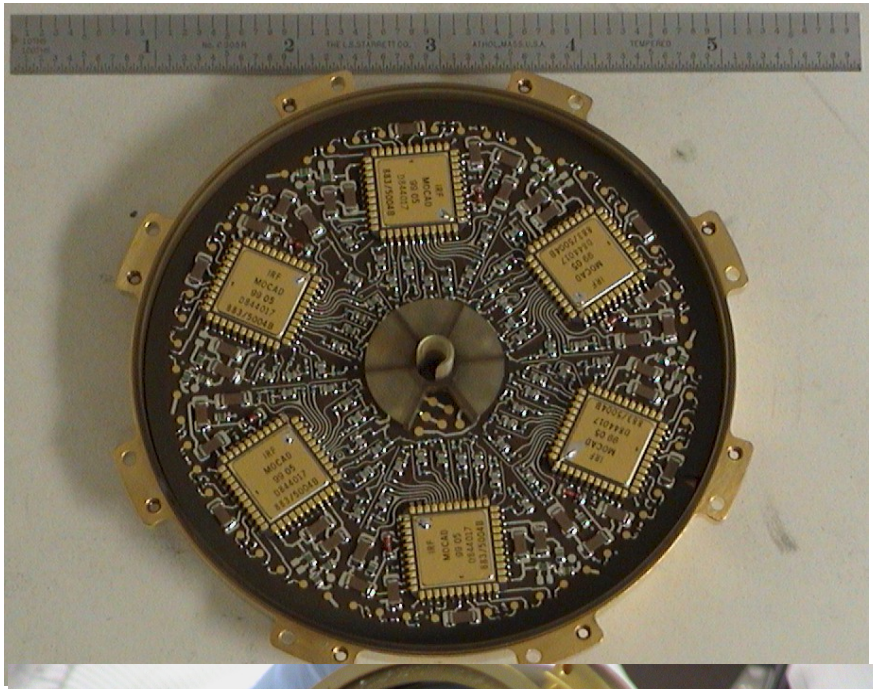
Improved IMA Anode

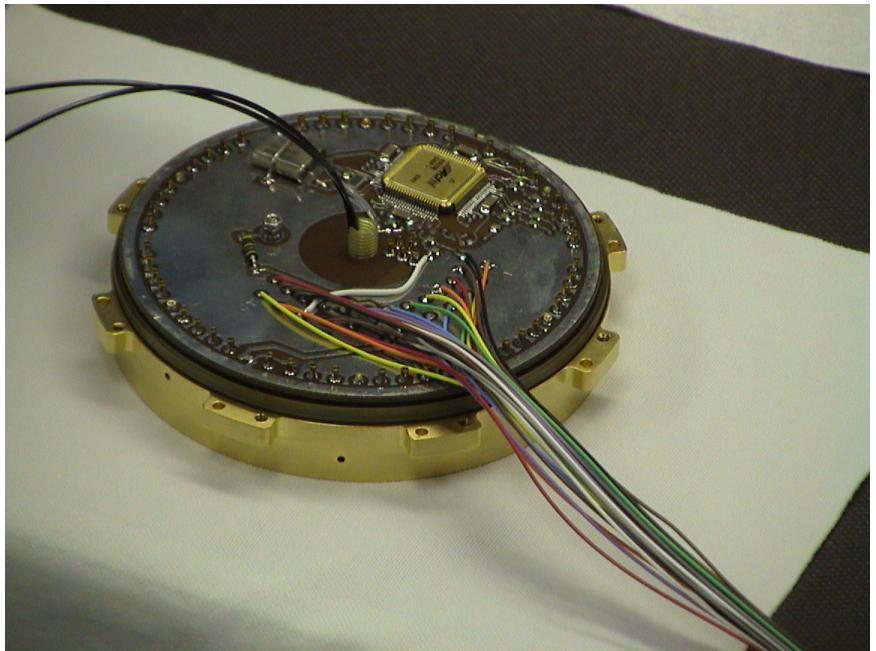


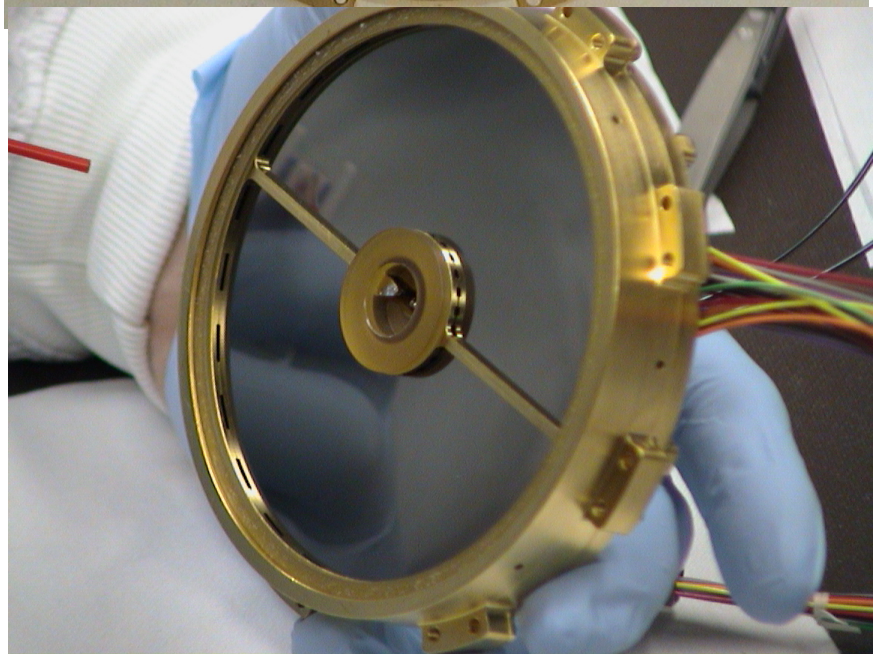
IMA Anode Back

IMA Anode Assembly

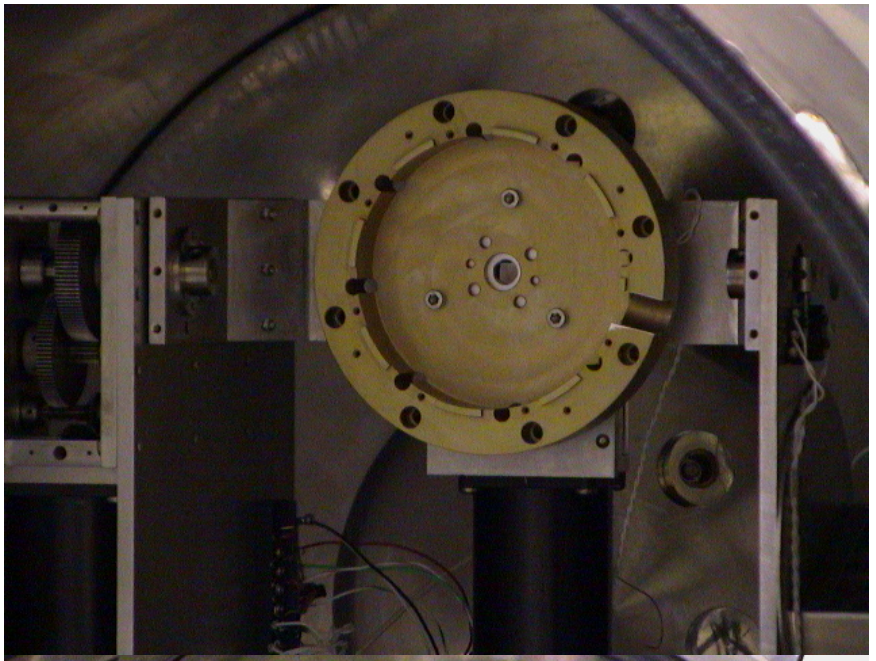


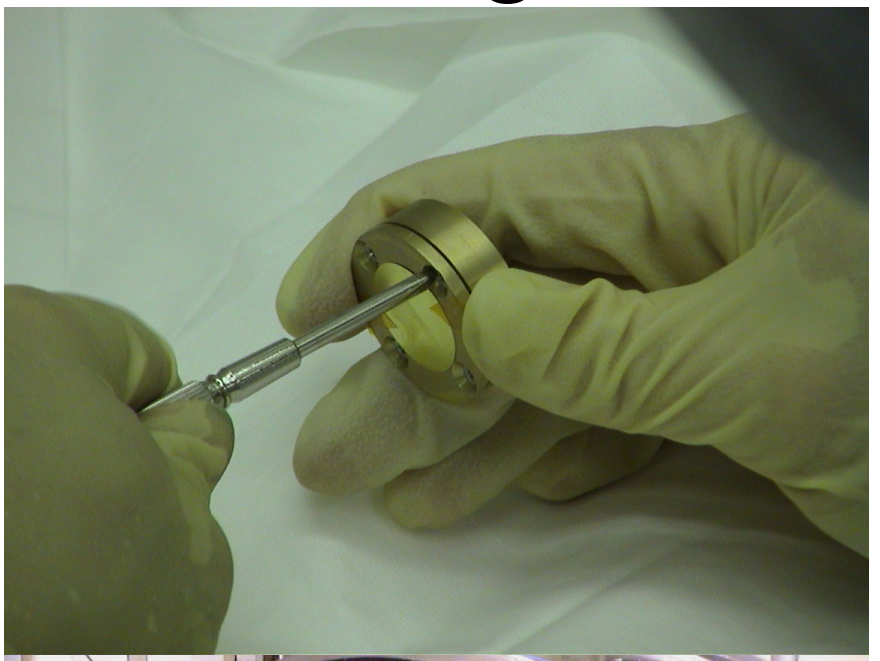


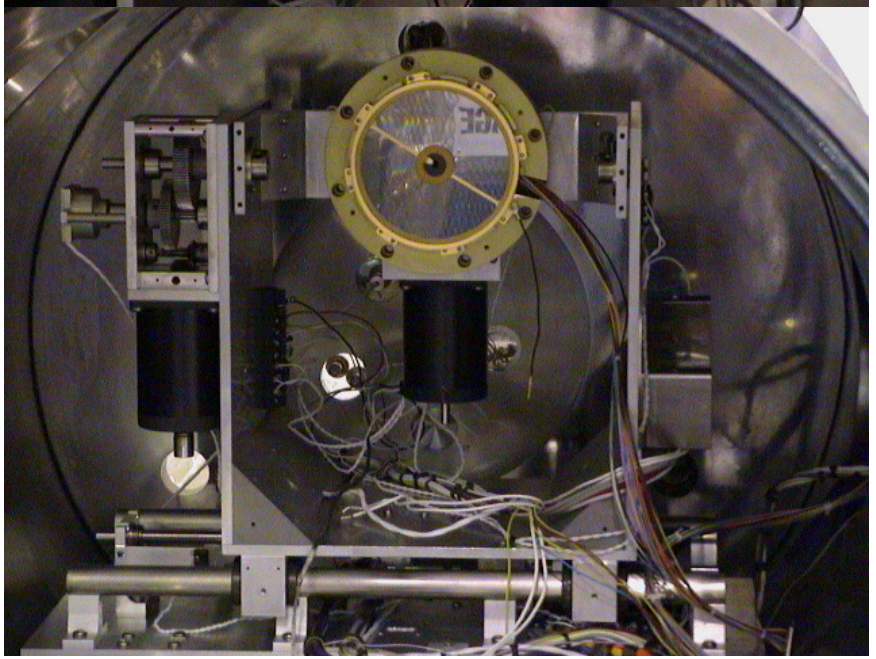


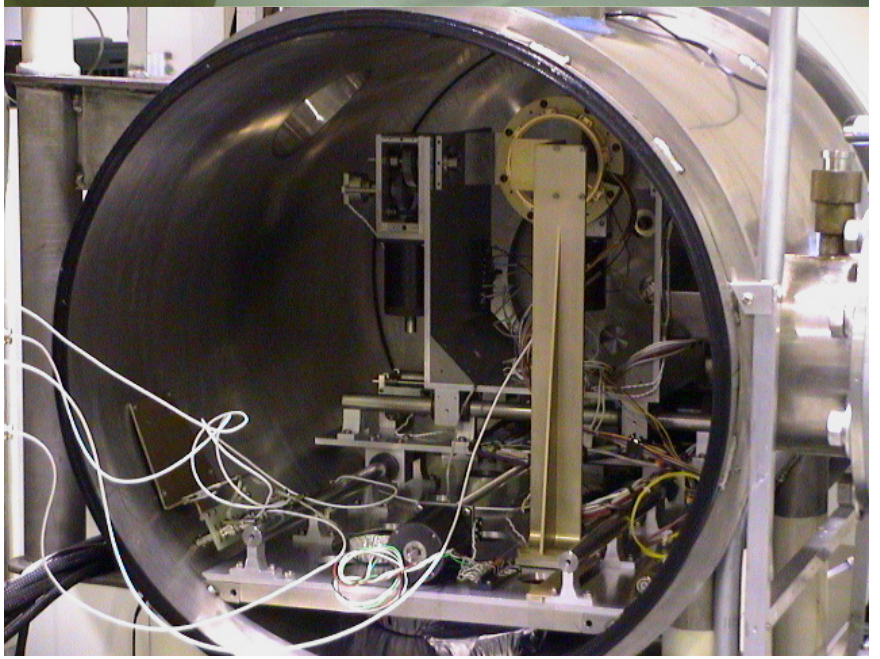


IMA Vacuum Testing









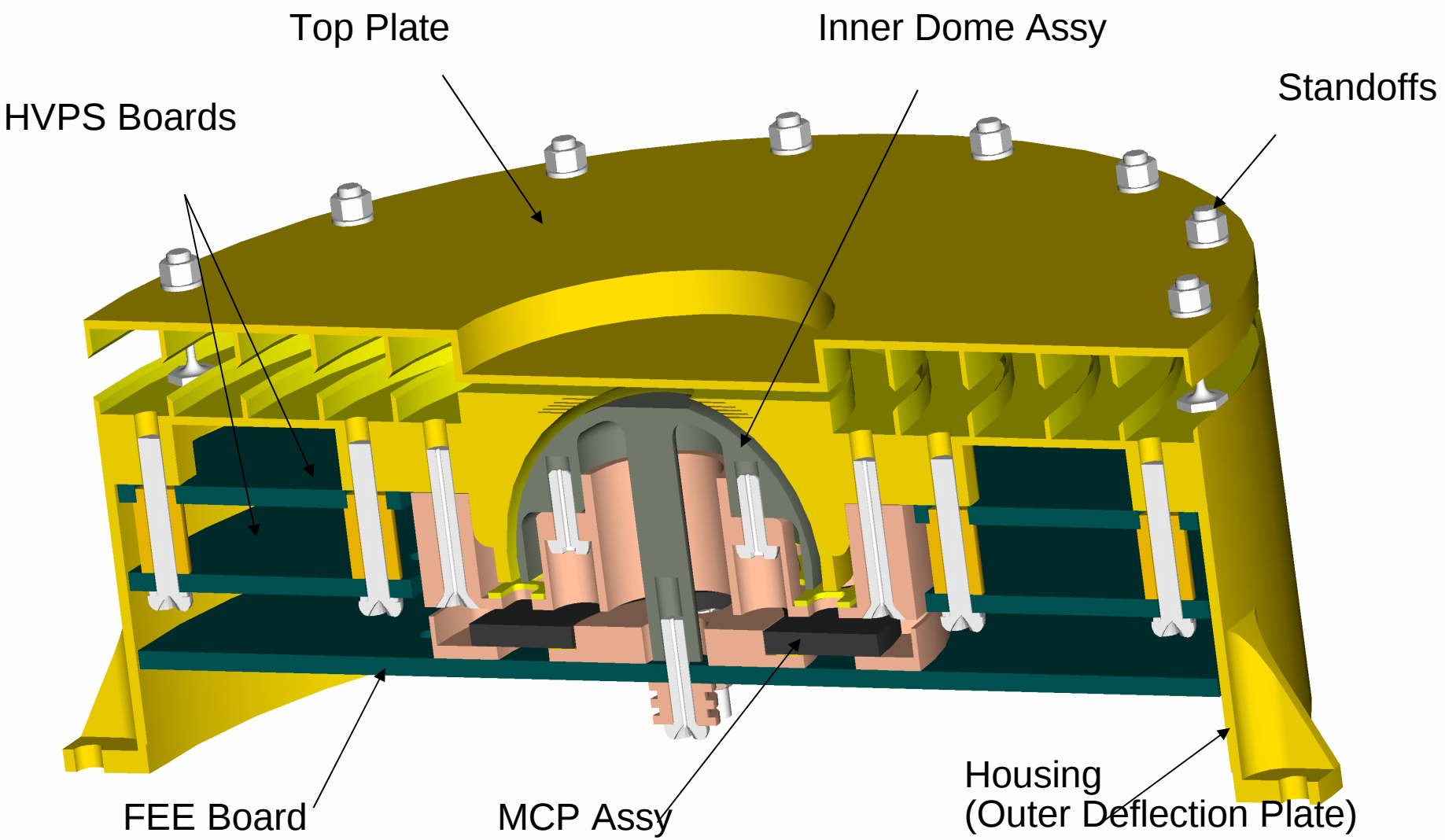
SwRI ELS Involvement

SwRI designed, built, and tested the ELS instrument and a flight spare ELS.
(MSSL participation)

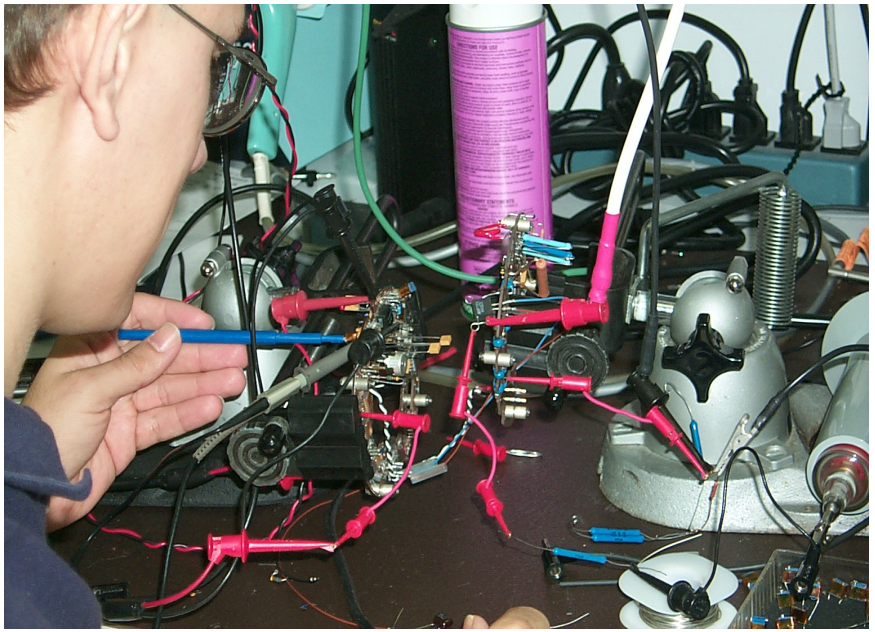
final calibration conducted at MSSL

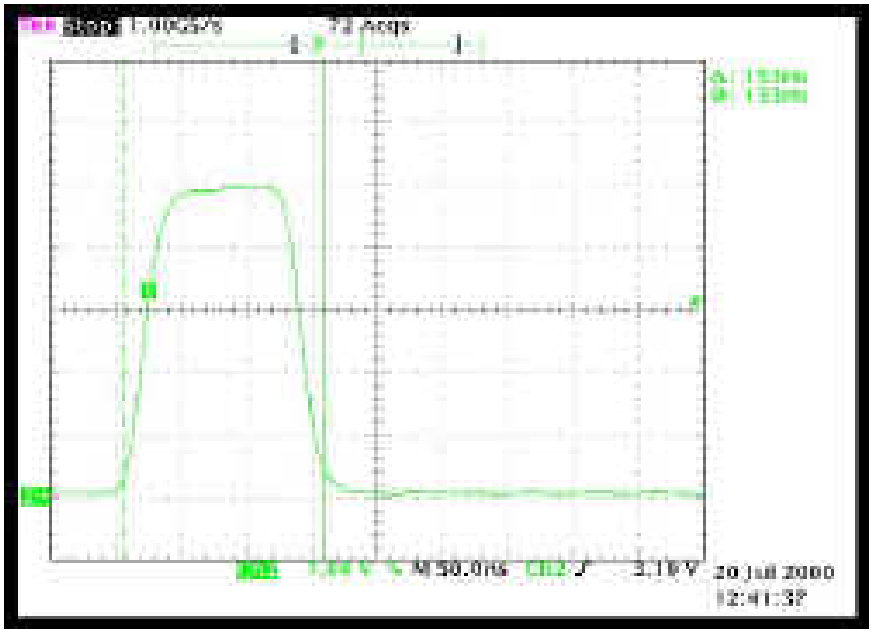
The ELS flight spare is part of the ASPERA-4 experiment on ESA's Venus Express.

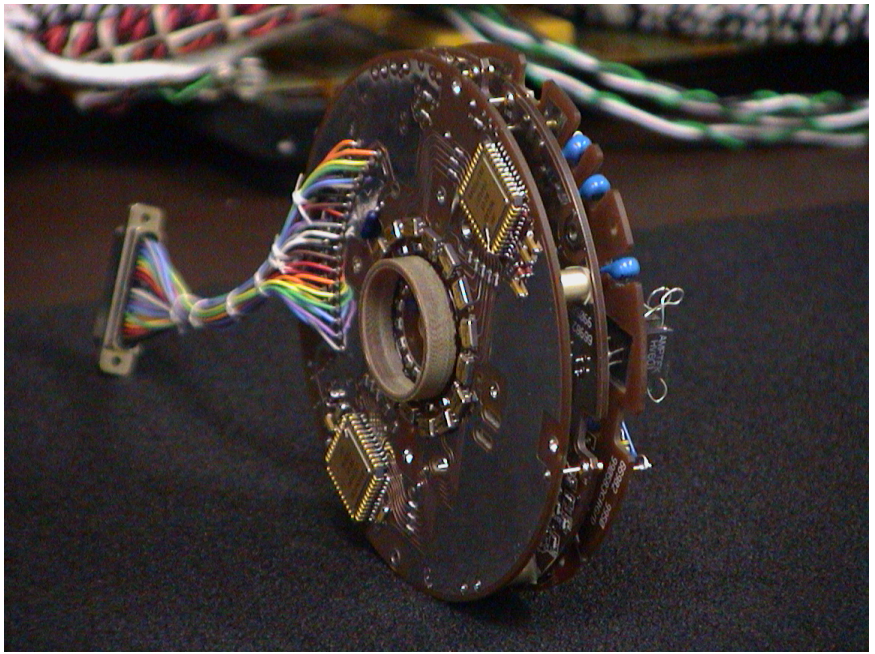
ELS Layout

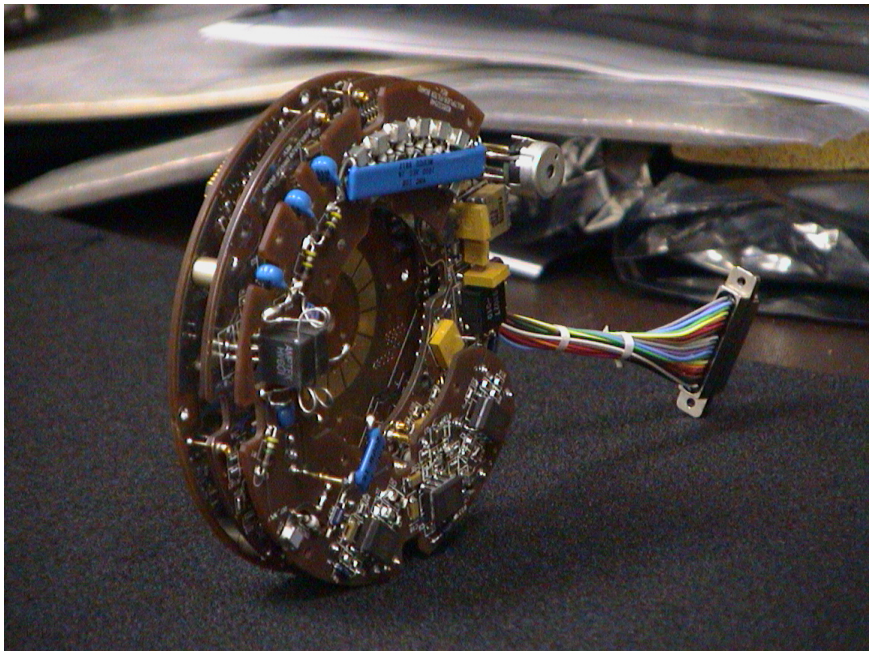

Top Plate
Inner Dome Assy
HVPS Boards
Standoffs
FEE Board
MCP Assy
Housing
(Outer Deflection Plate)

ELS Electronics

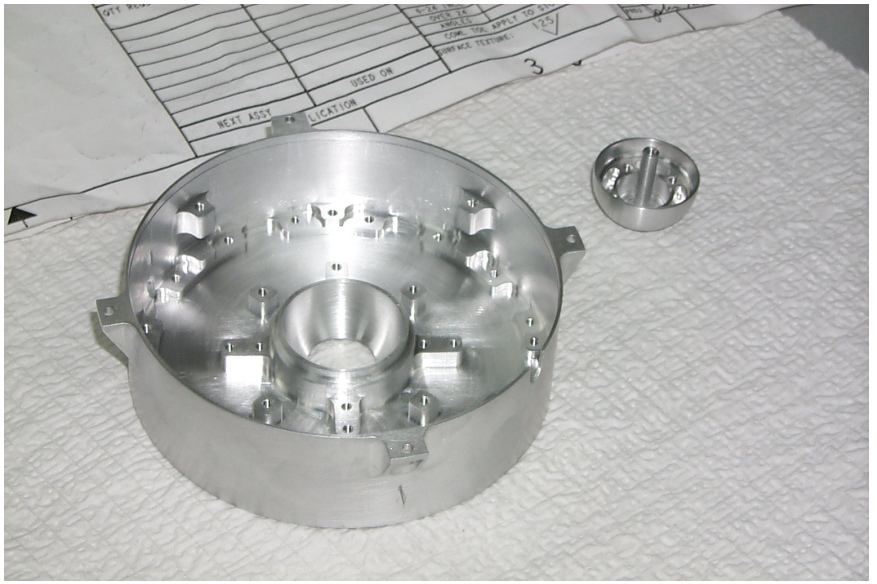




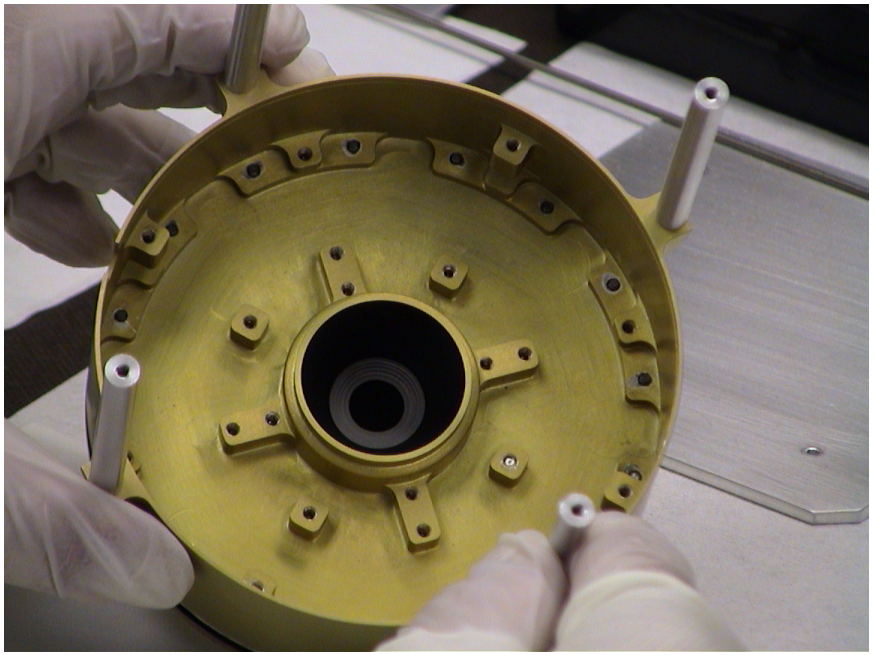


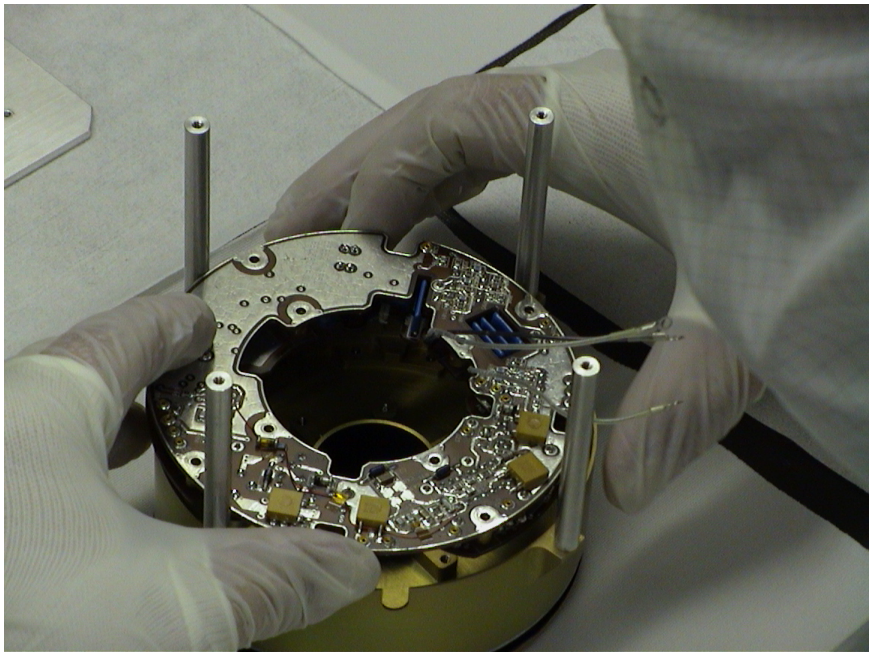


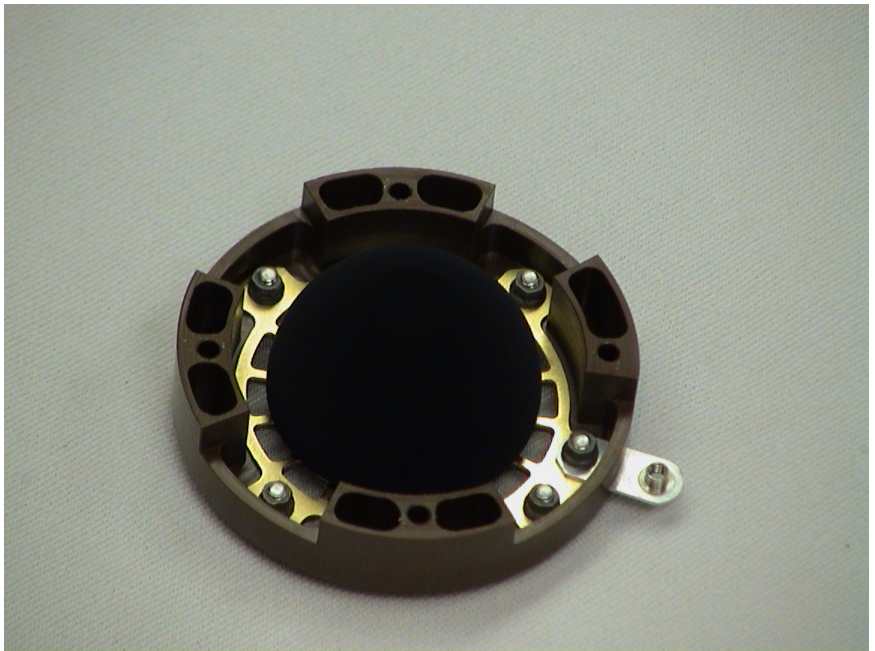
ELS Housing

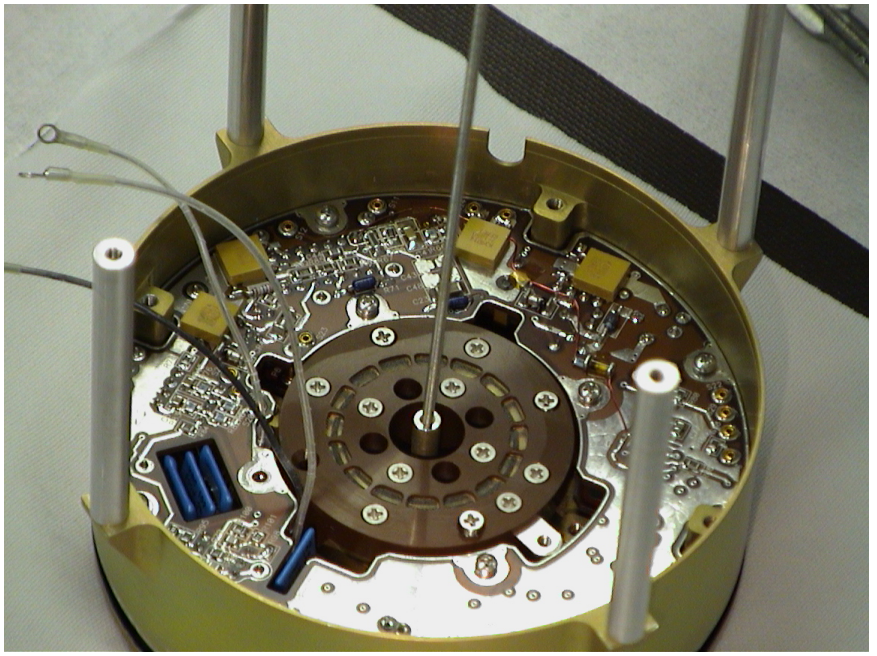


ELS Power & Deflection Systems

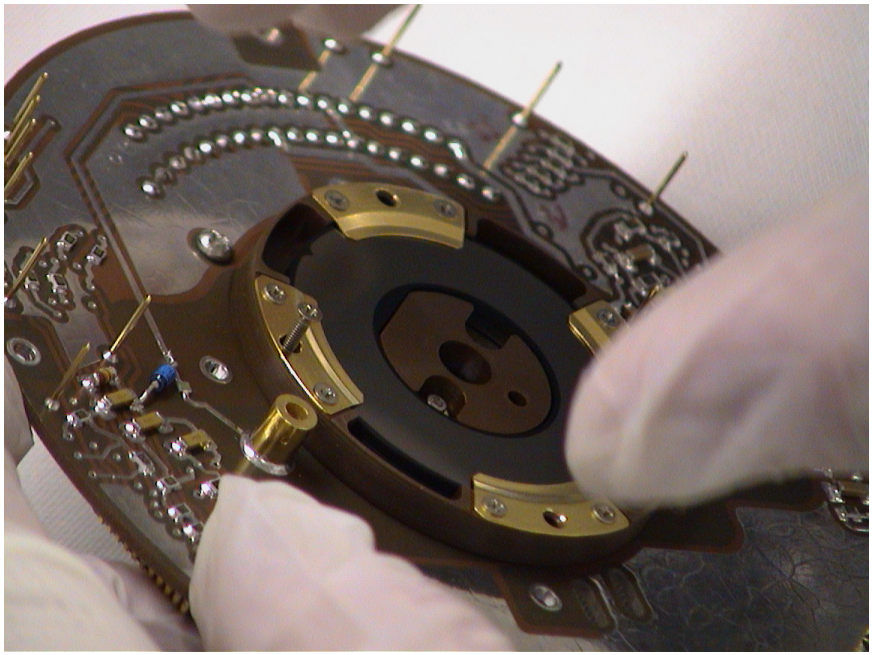


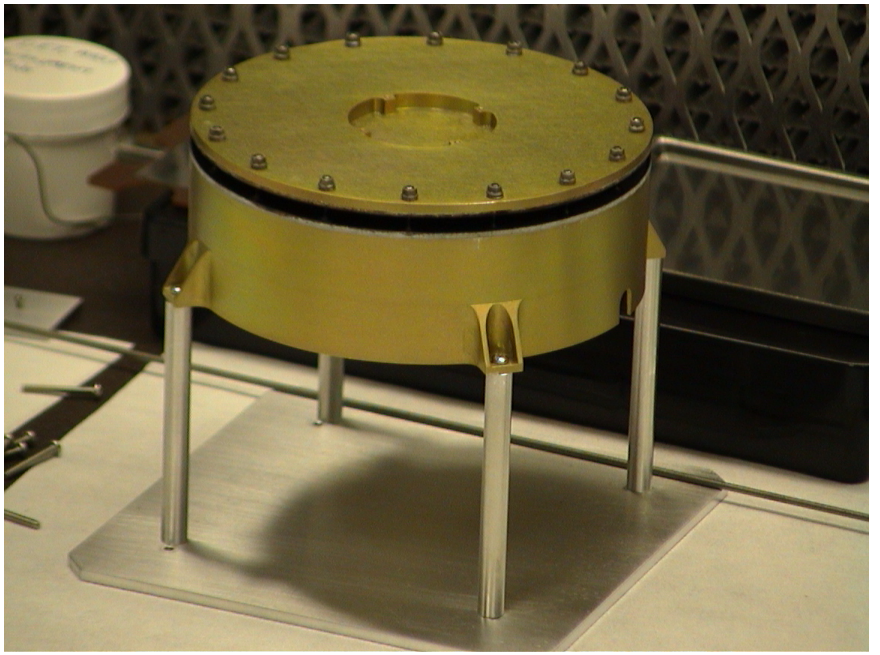


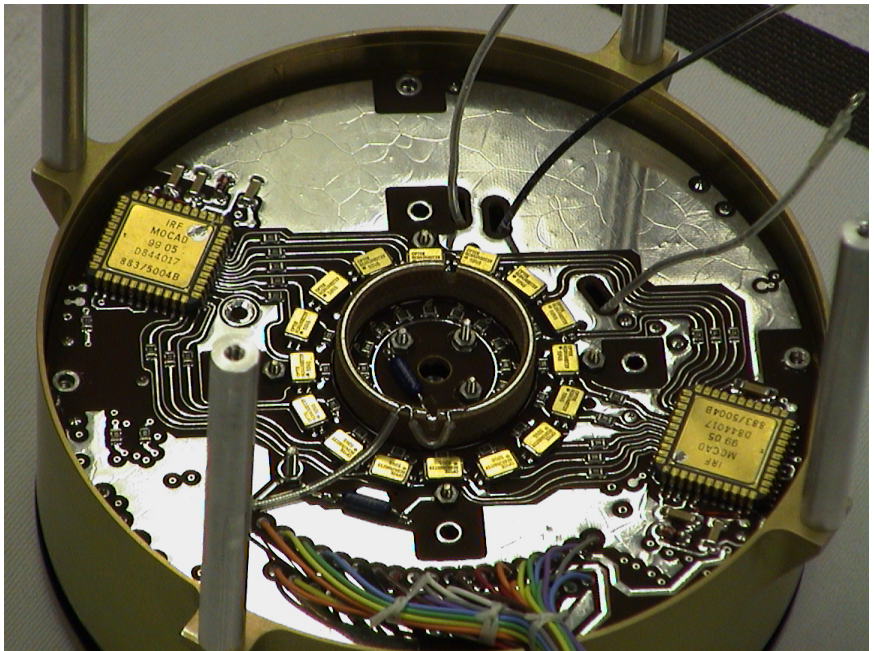


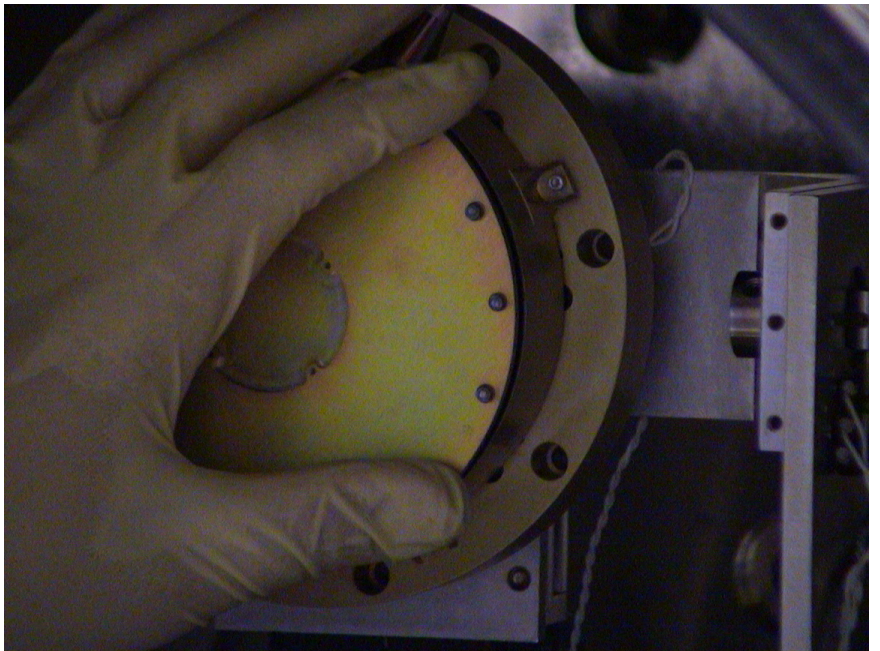


ELS Anode

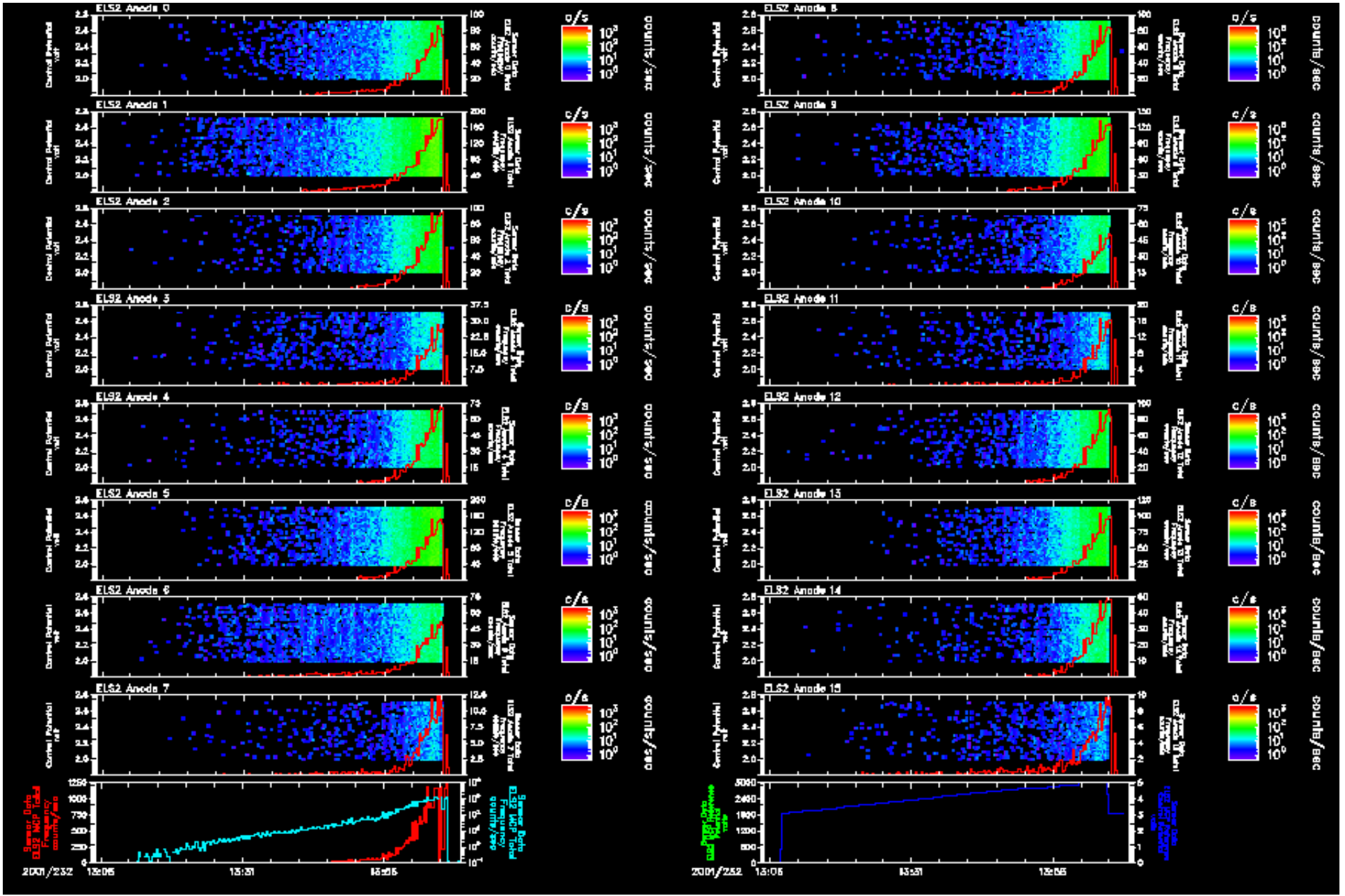




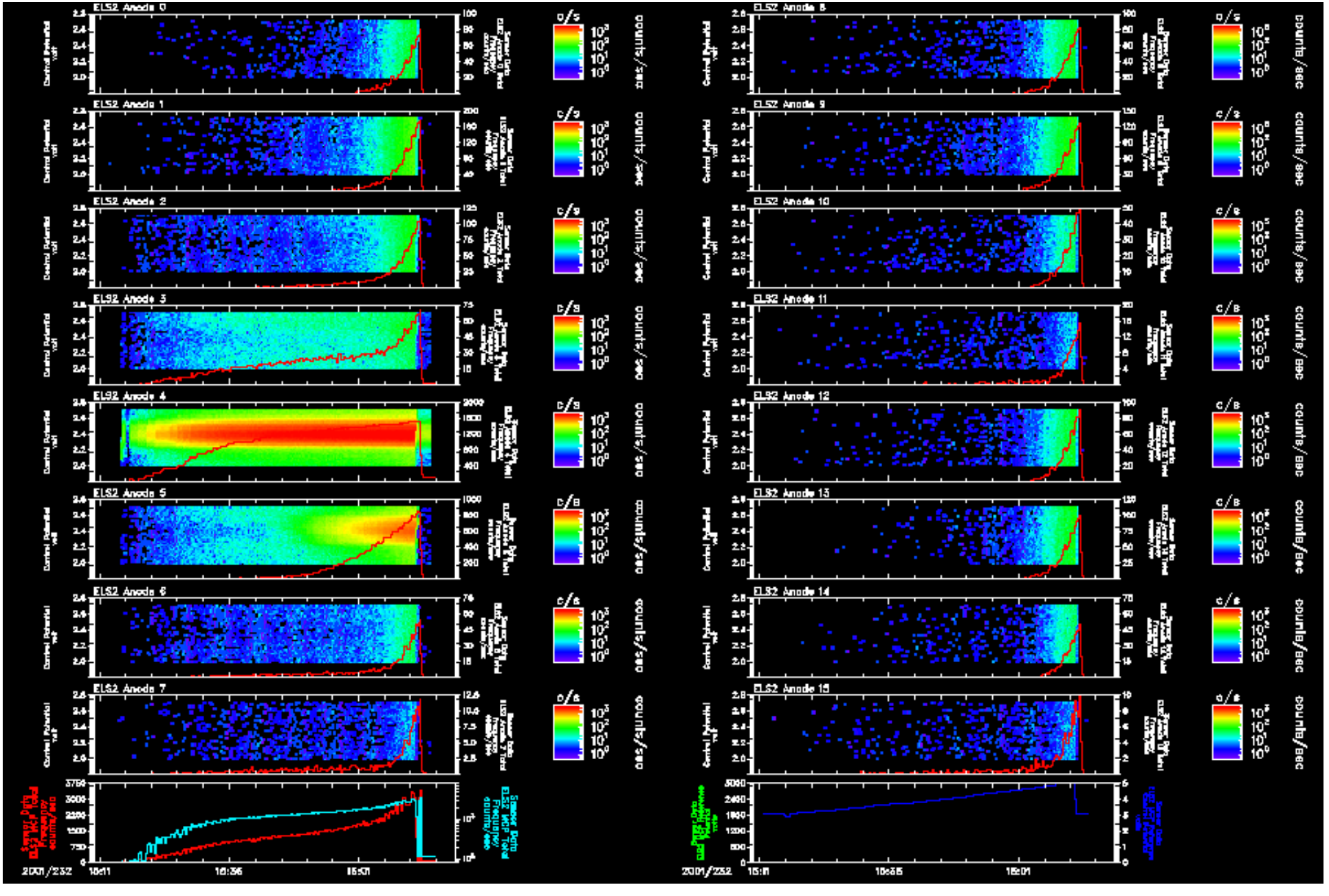




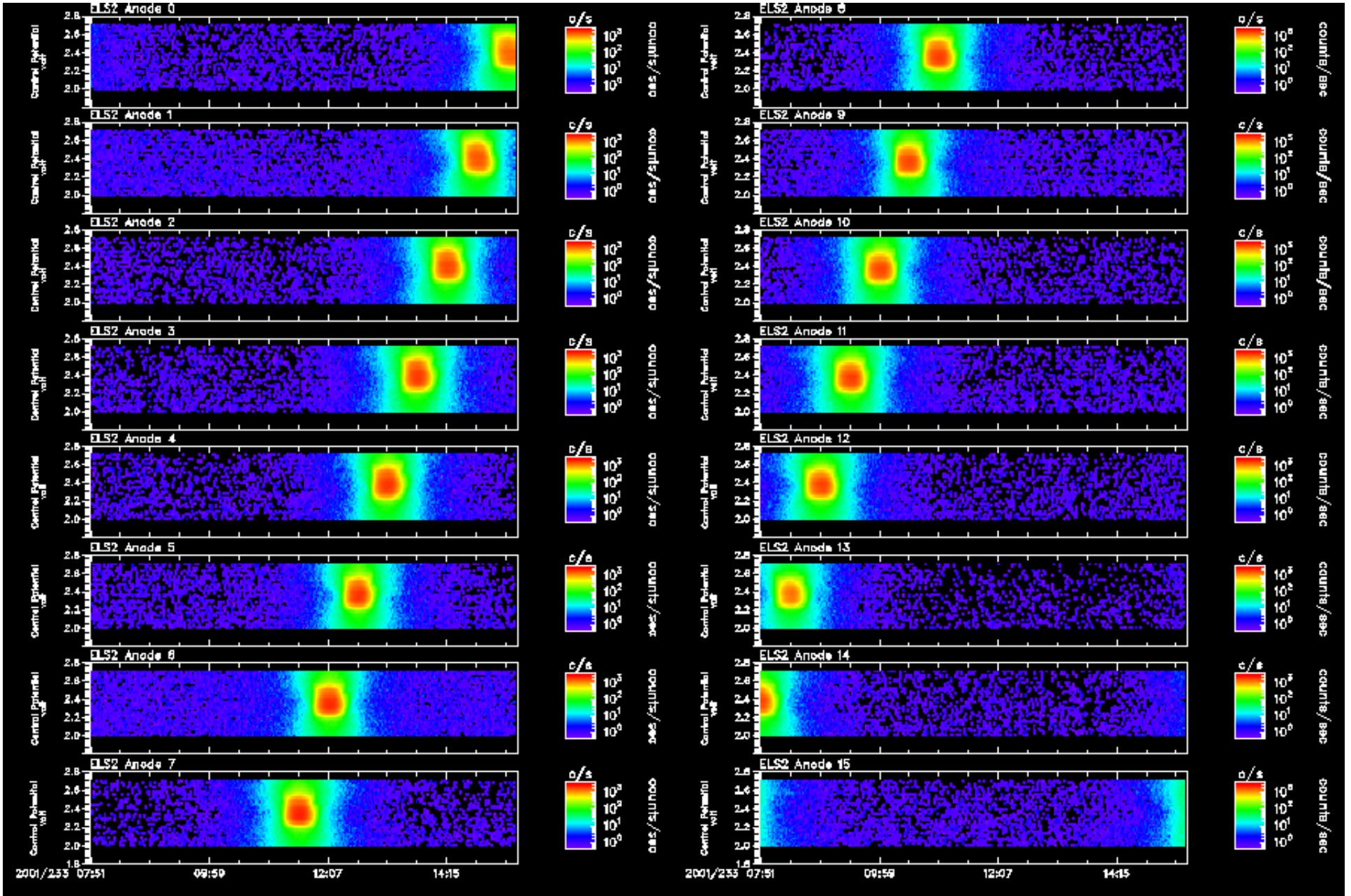
ELS Active/No Source



ELS Active/Source Active



ELS Testing


ELS2 Anode 0
ELS2 Anode 1
ELS2 Anode 2
ELS2 Anode 3
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ELS2 Anode 6
ELS2 Anode 7
ELS2 Anode 8
ELS2 Anode 9
ELS2 Anode 10
ELS2 Anode 11
ELS2 Anode 12
ELS2 Anode 13
ELS2 Anode 14
ELS2 Anode 15
Control Potential volt
c/s
counts/sec
2001/235 07:51
09:59
12:07
14:15

Software

Sandee Jeffers - PM post launch

Andrew Galus[1], Carrie Gonzalez, Andrew Hudson[1], Kevin Jennings[5], Anders Johansson[1], Michael Madrigal[6], William Motley, Joey Mukherjee, Michael Muller, Richard Murphy[7], Jeran Pardue[1], David Preciado[5], Louis Vela[1].

[1]No longer at SwRI, [2]Converted to TA, [3]Retired from SwRI, [4]Now in Div 18, [5]Private Contractor, [6]Div 16, [7]Now at ITC, [8]Deceased

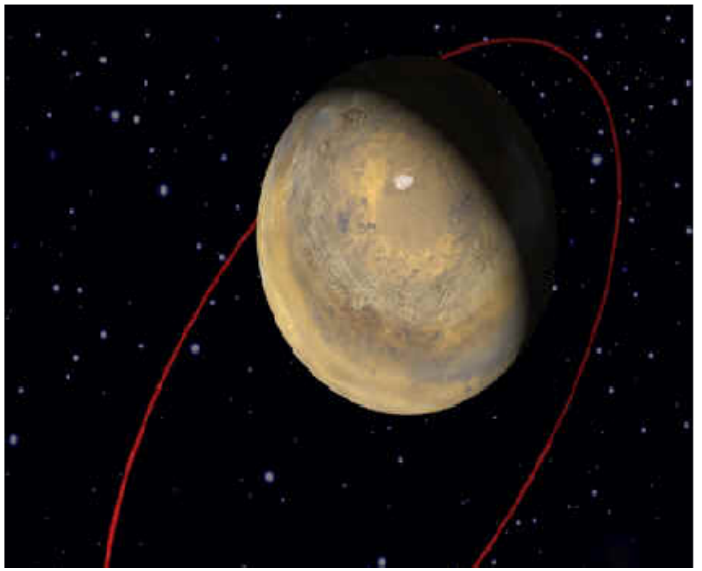
Continual Software Tasks

1) Process all ASPERA-3 telemetry into IDFS format files: IMA, ELS, NPI, NPD, MU, Scanner, and Sun Sensors within 24 hours.
2) Generate Spacecraft Orbit and Attitude within 24 hours of availability.
3) Maintain EPO web site with quick-look ASPERA-3 Data.
4) Process and support correlative data sets.
5) Submit ASPERA-3 data to ESA and NASA long term data archives.
6) Support Science Activities.

http://www.aspera-3.org

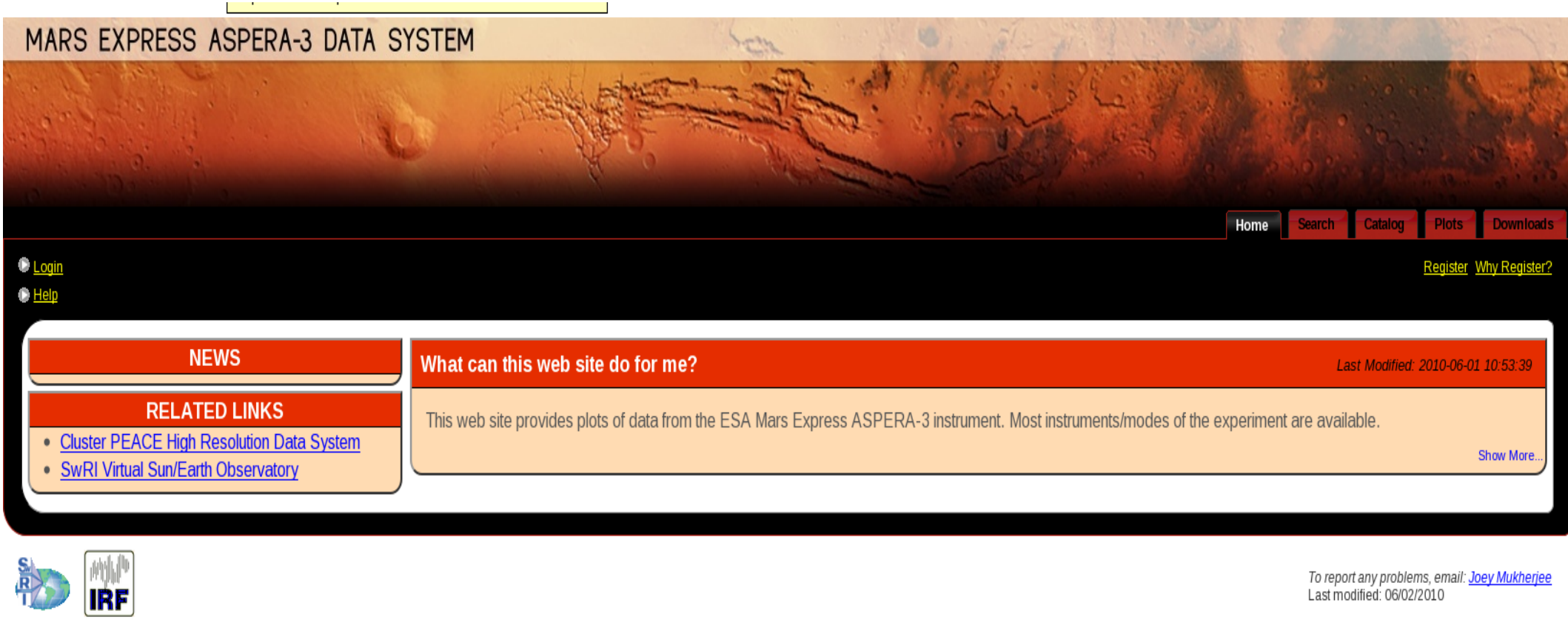
- **Where did the Martian water go?**
- **Is it lost or simply frozen?**
- **If it's lost, what enabled it to escape the planet?**
- **If it's frozen, where is the tremendous amount of water stored?**

These are the questions that the ASPERA-3 experiment is helping to answer through the study of the solar wind/atmosphere interaction in near-Mars space. This device is onboard the Mars Express spacecraft launched in June of 2003. No instrument with similar scientific objectives has flown or is scheduled to be flown to Mars.

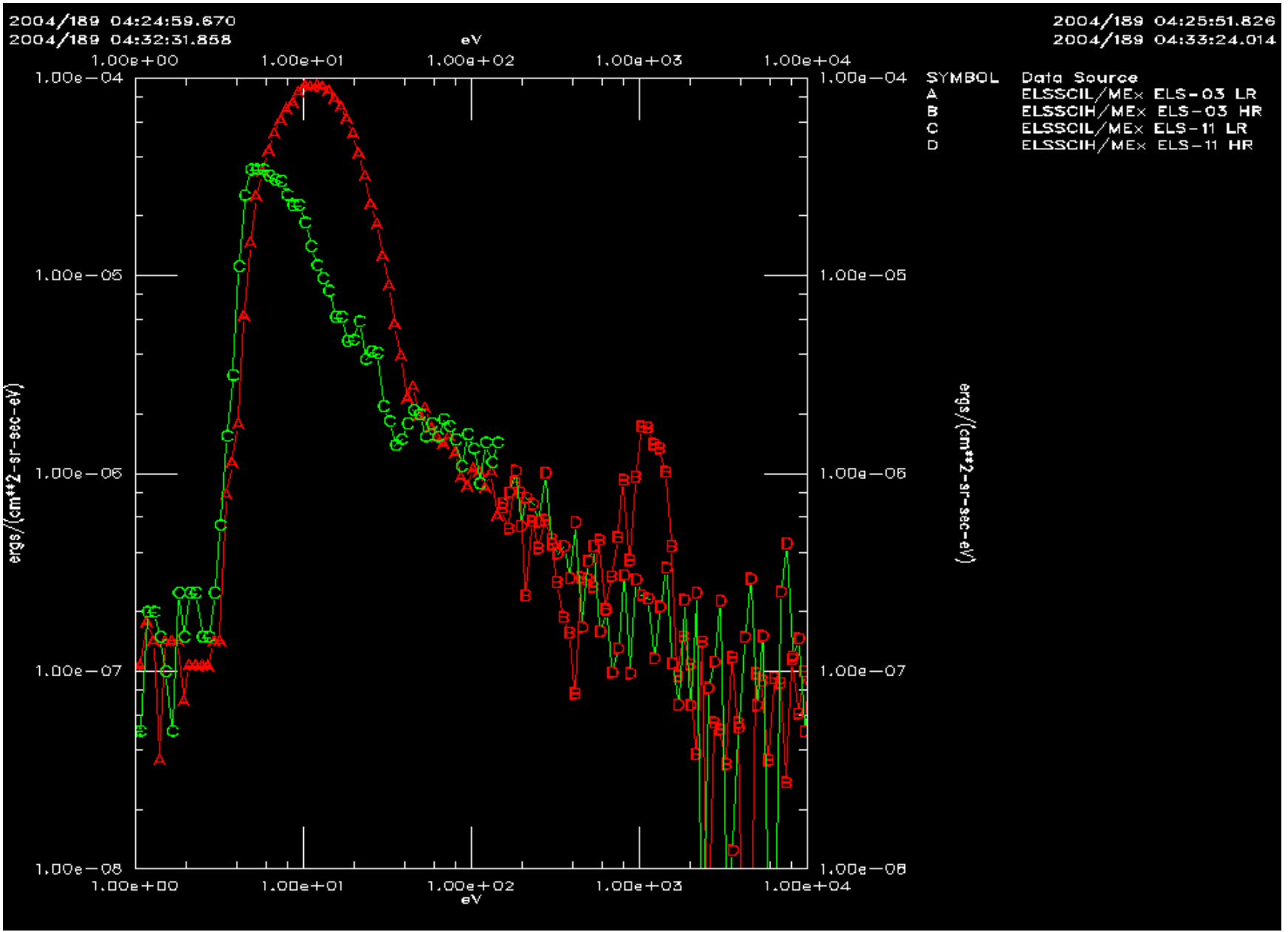


Collaborative Studies:

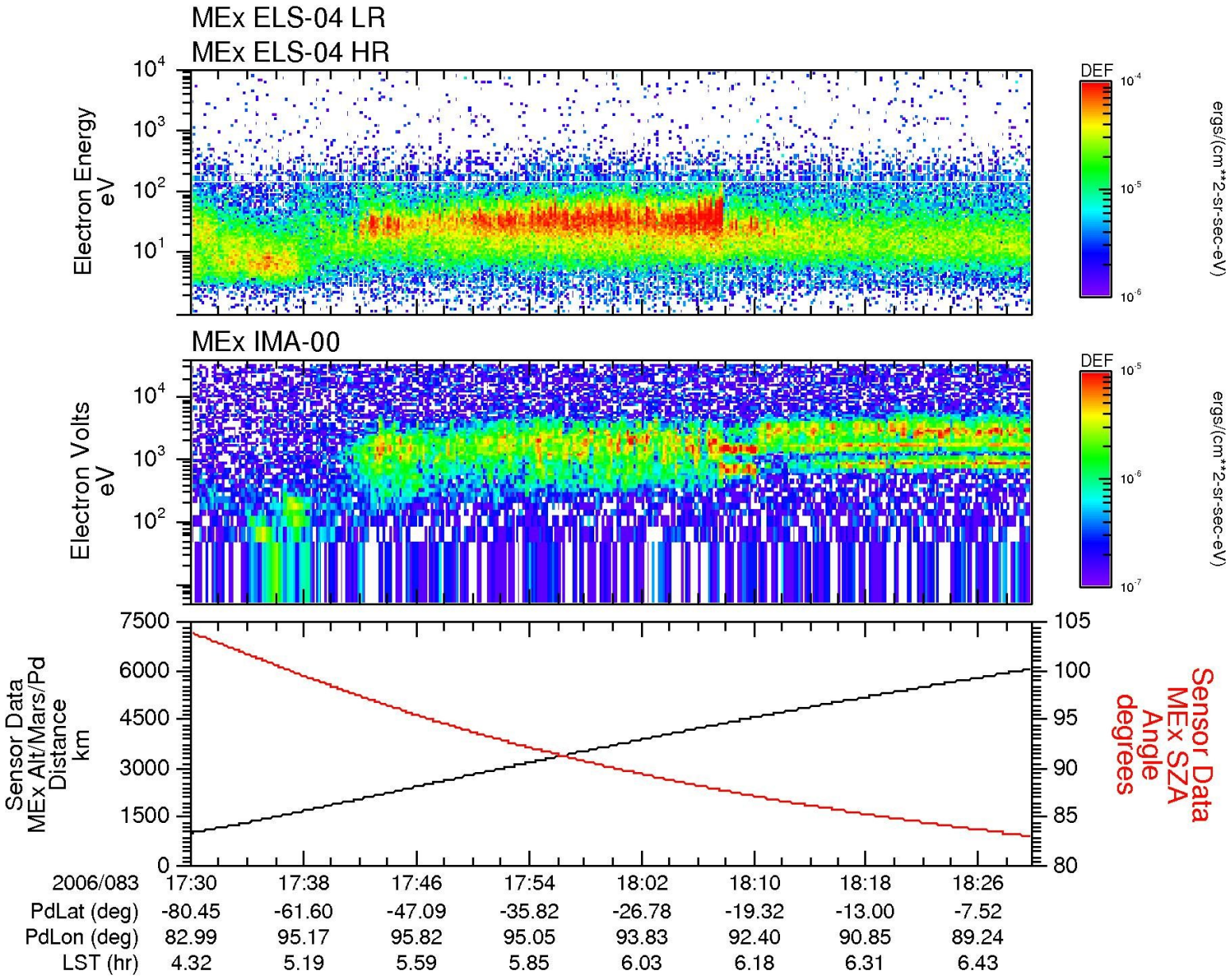
ASPERA-3 Data and Plots: http://mexdata.space.swri.edu



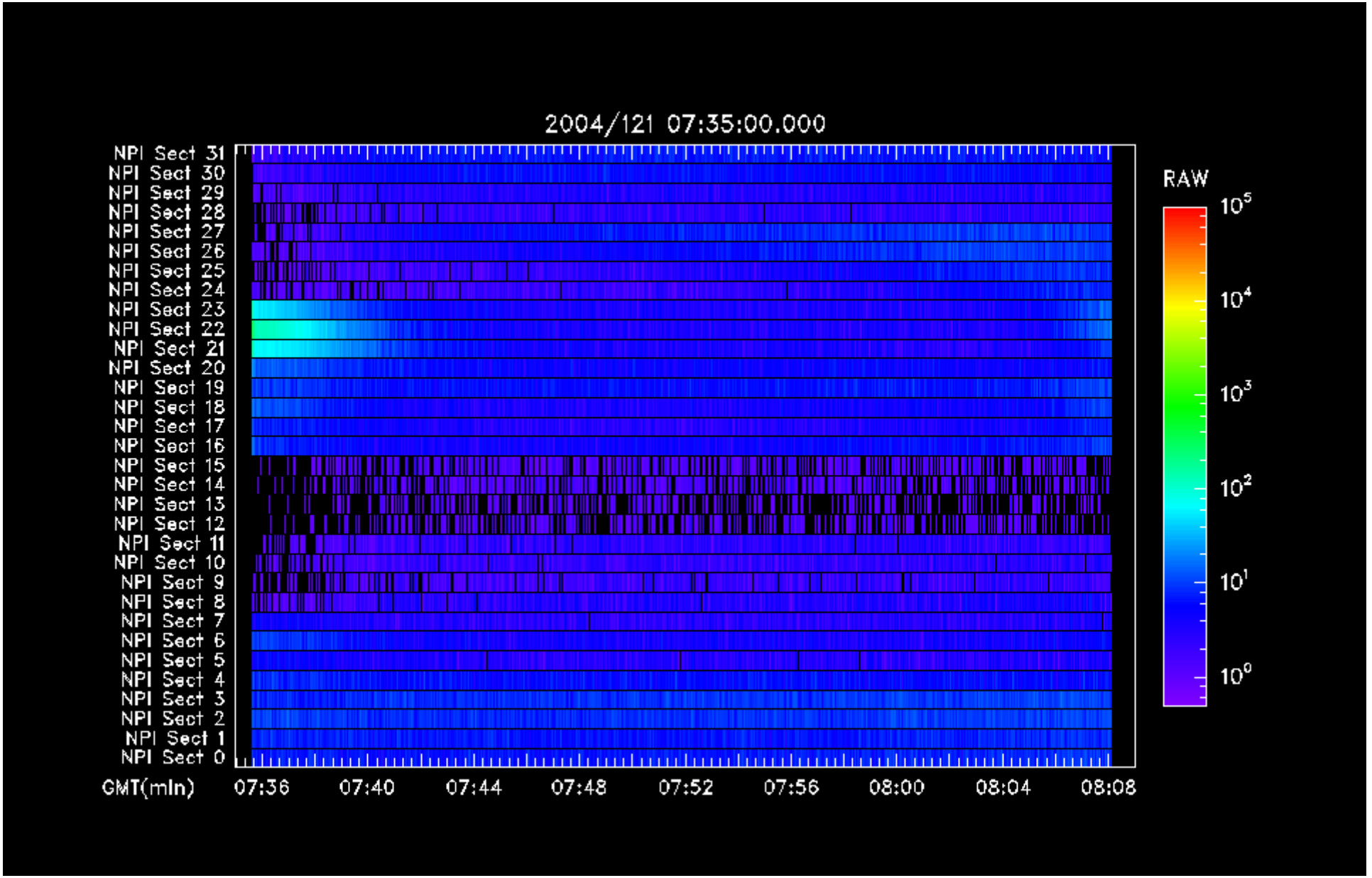
Spectrum Example



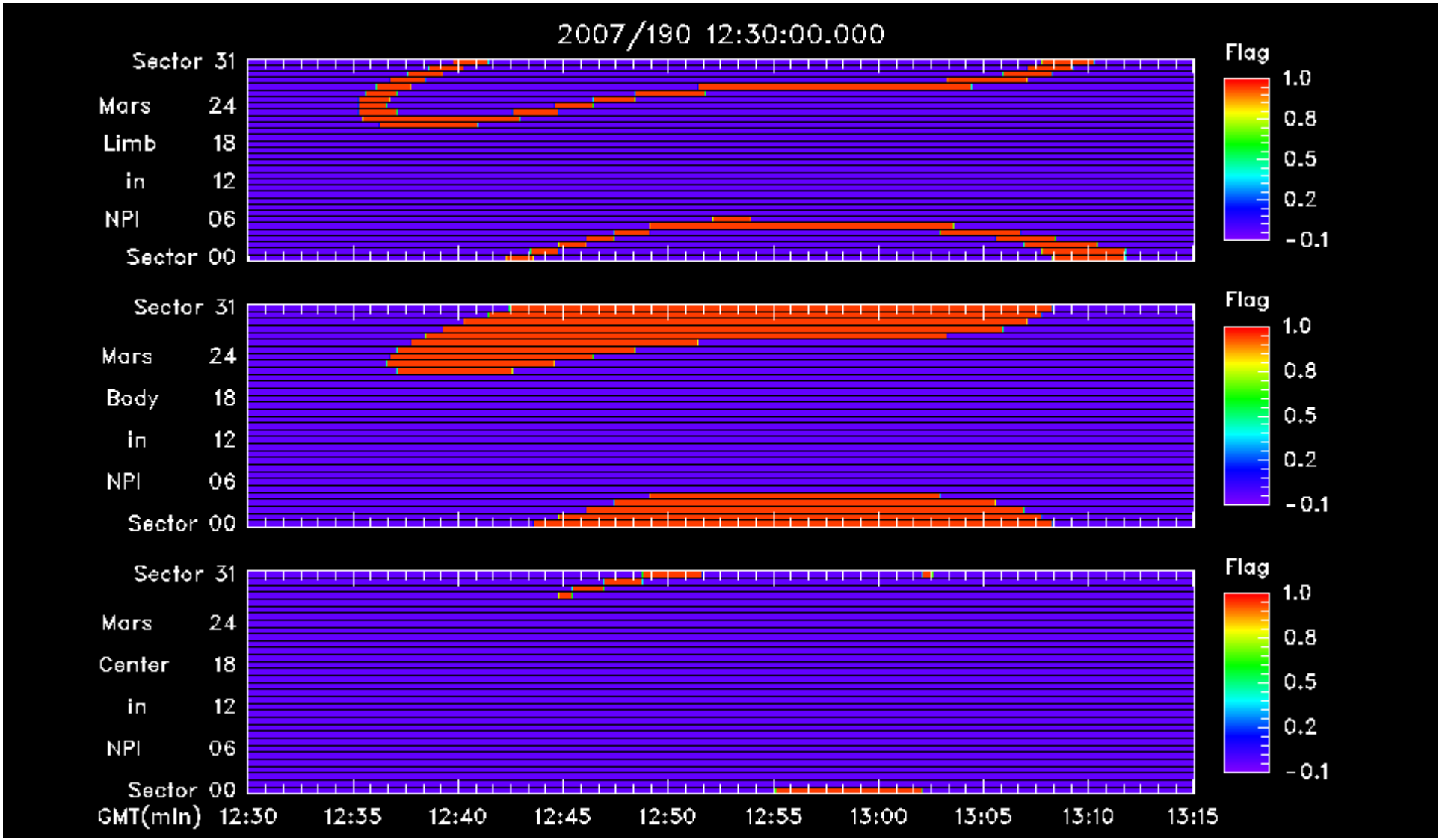
Spectrogram/Line Plot Example



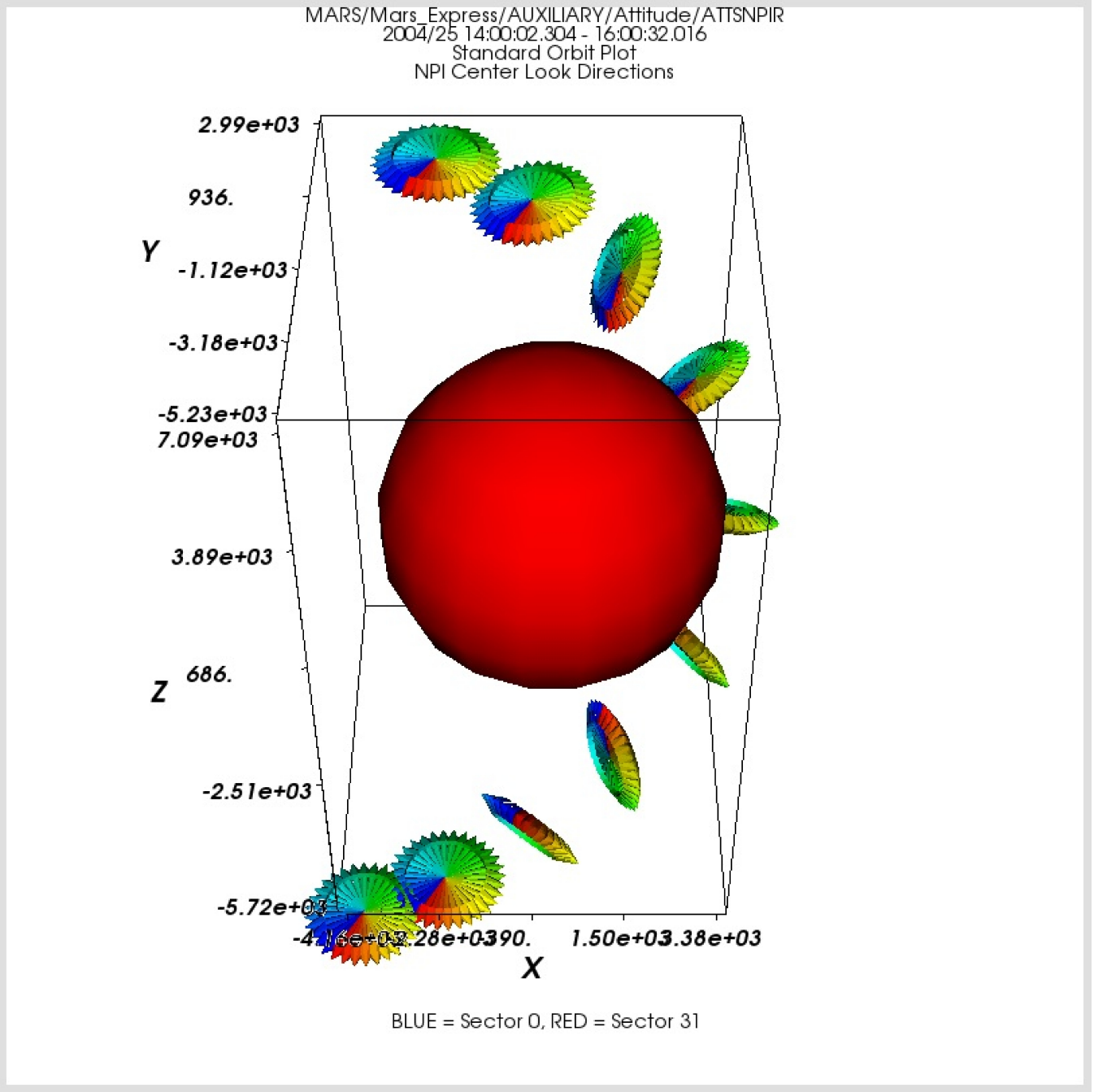
NPI Strip Image Example



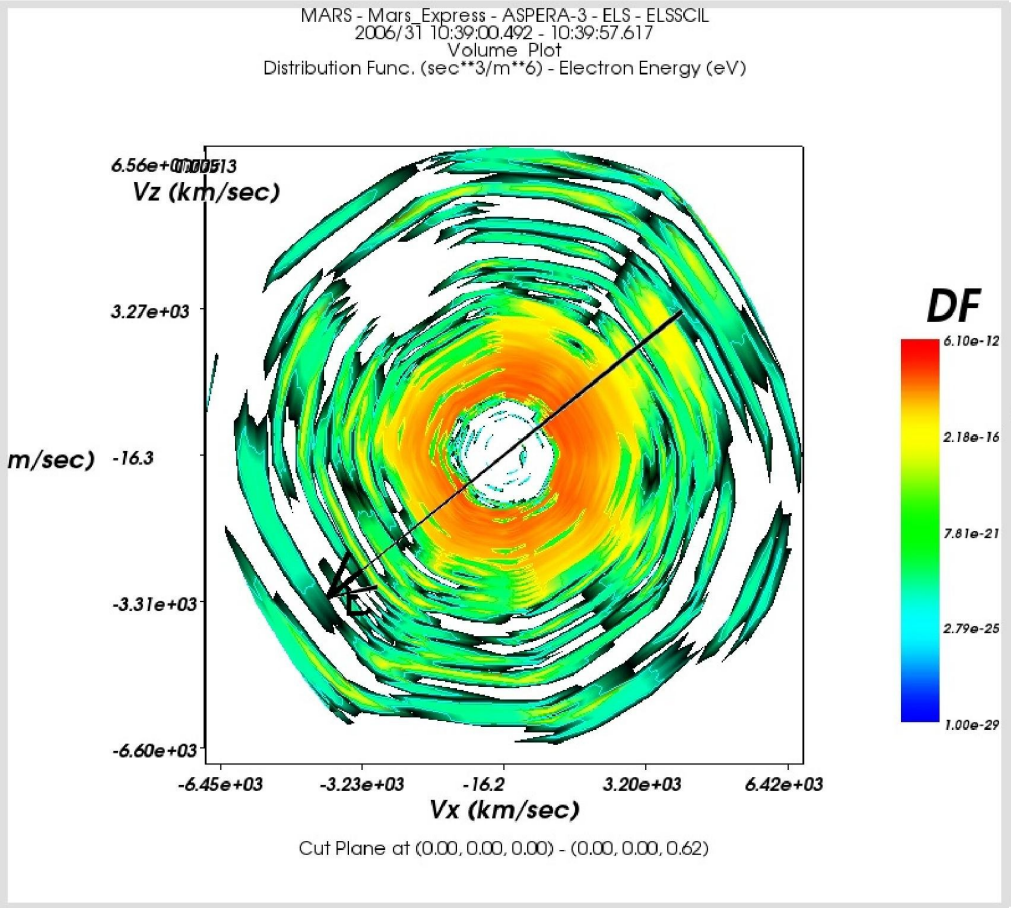
NPI View of Mars Example

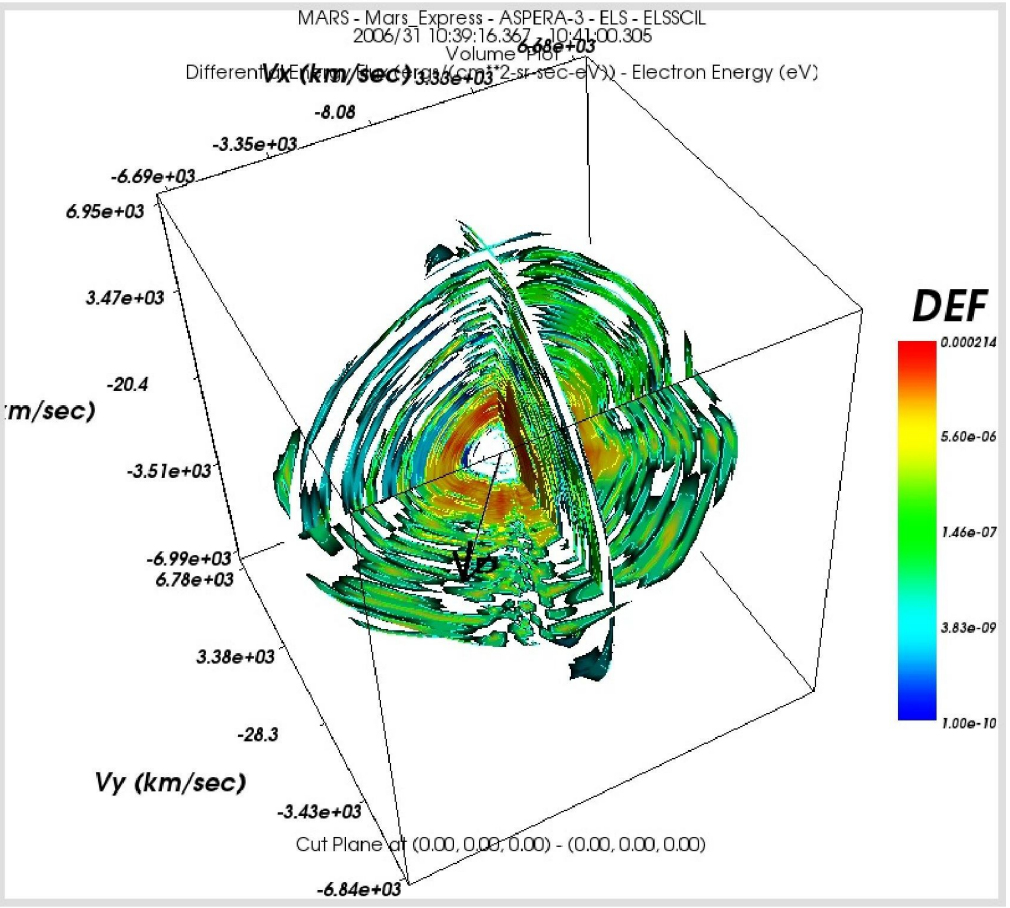


3D Interactive Orbit Plot Example

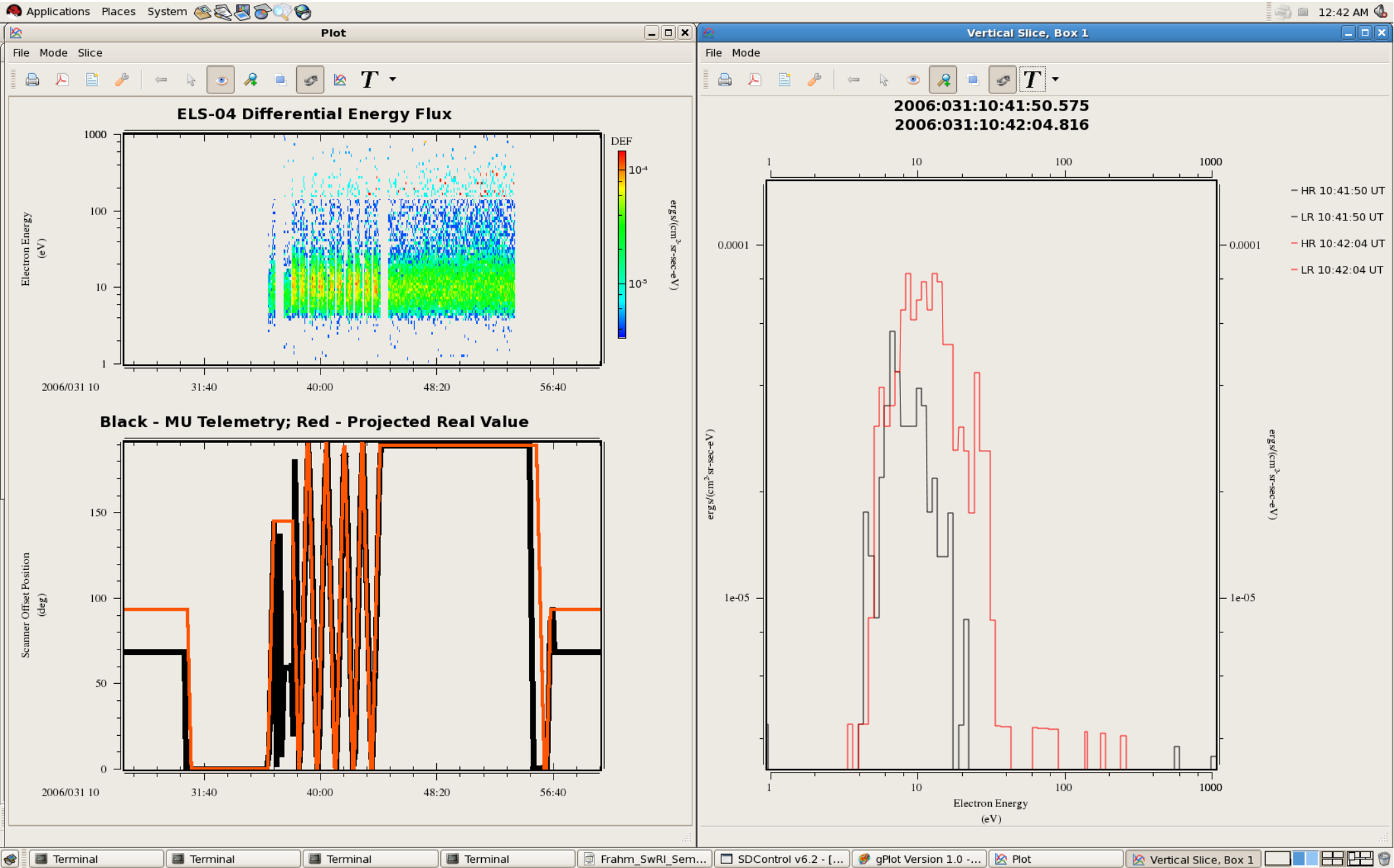


Examples of Contours





gPlot Example



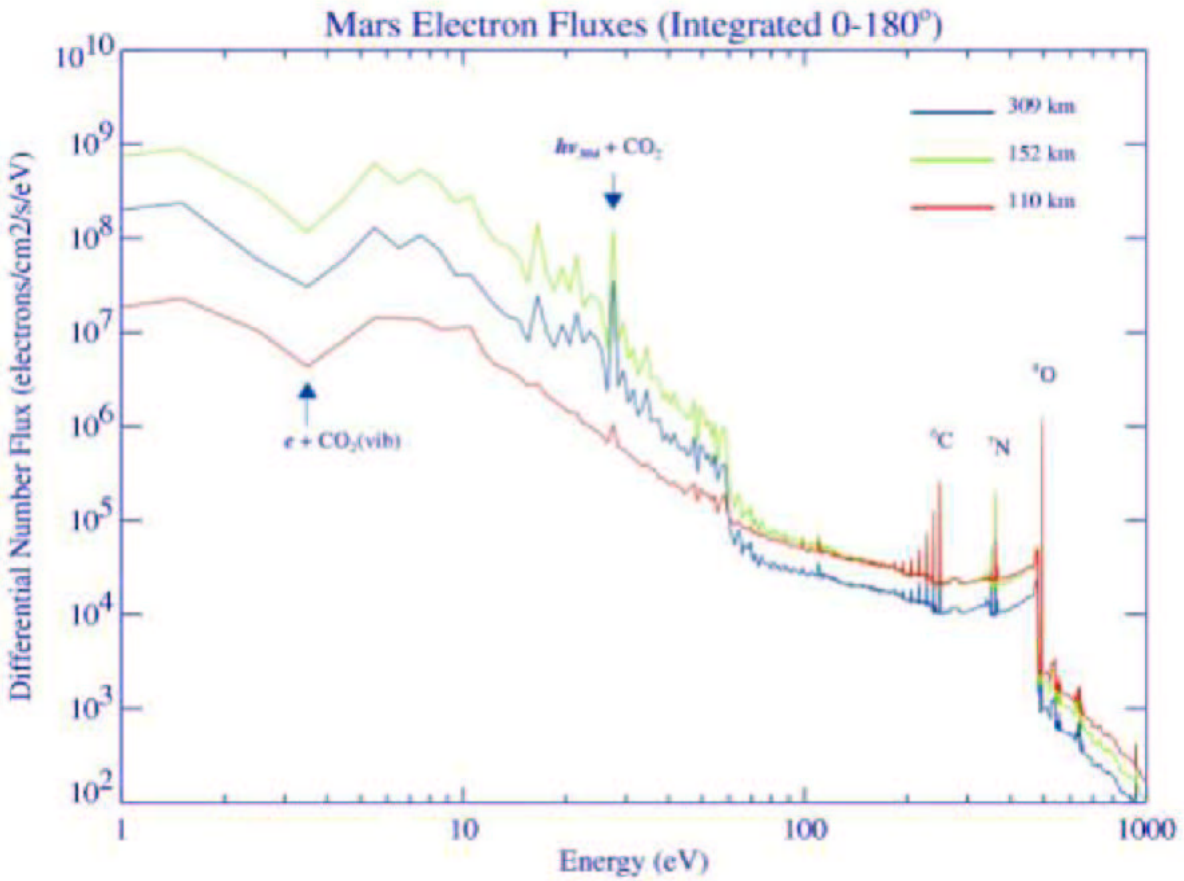
Science

David Winningham[2] - US PI

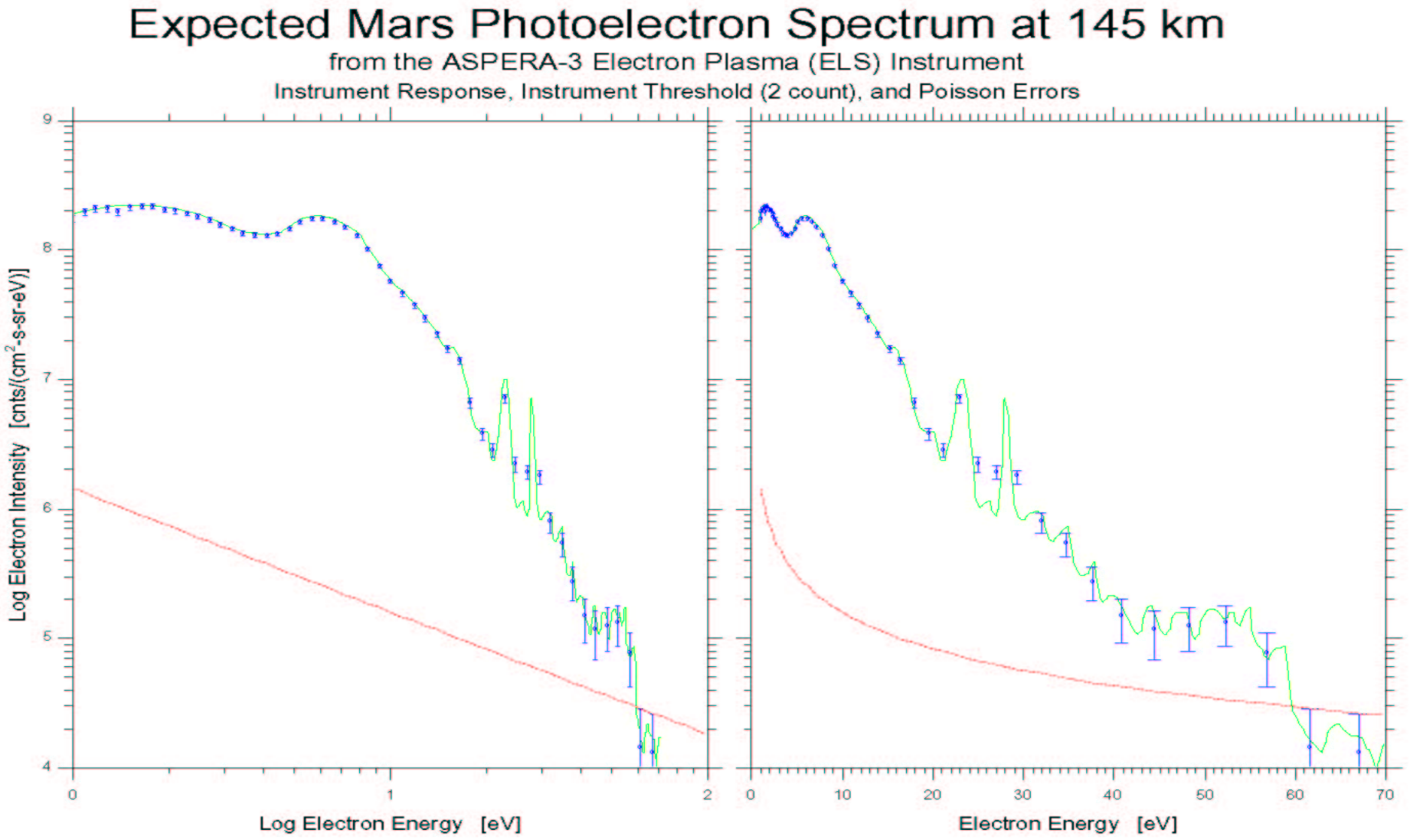
Kathy Coers, Rudy Frahm (ASPERA Co-I), Rick Link[1],
Stefano Livi (ASPERA-3 Co-I), Venissa Preciado, Christina McCarty,
Jim Sharber[2] (ASPERA Co-I), Dave Slater.

[1]No longer at SwRI, [2]Converted to TA, [3]Retired from SwRI, [4]Now in Div 18, [5]Private Contractor, [6]Div 16, [7]Now at ITC, [8]Deceased

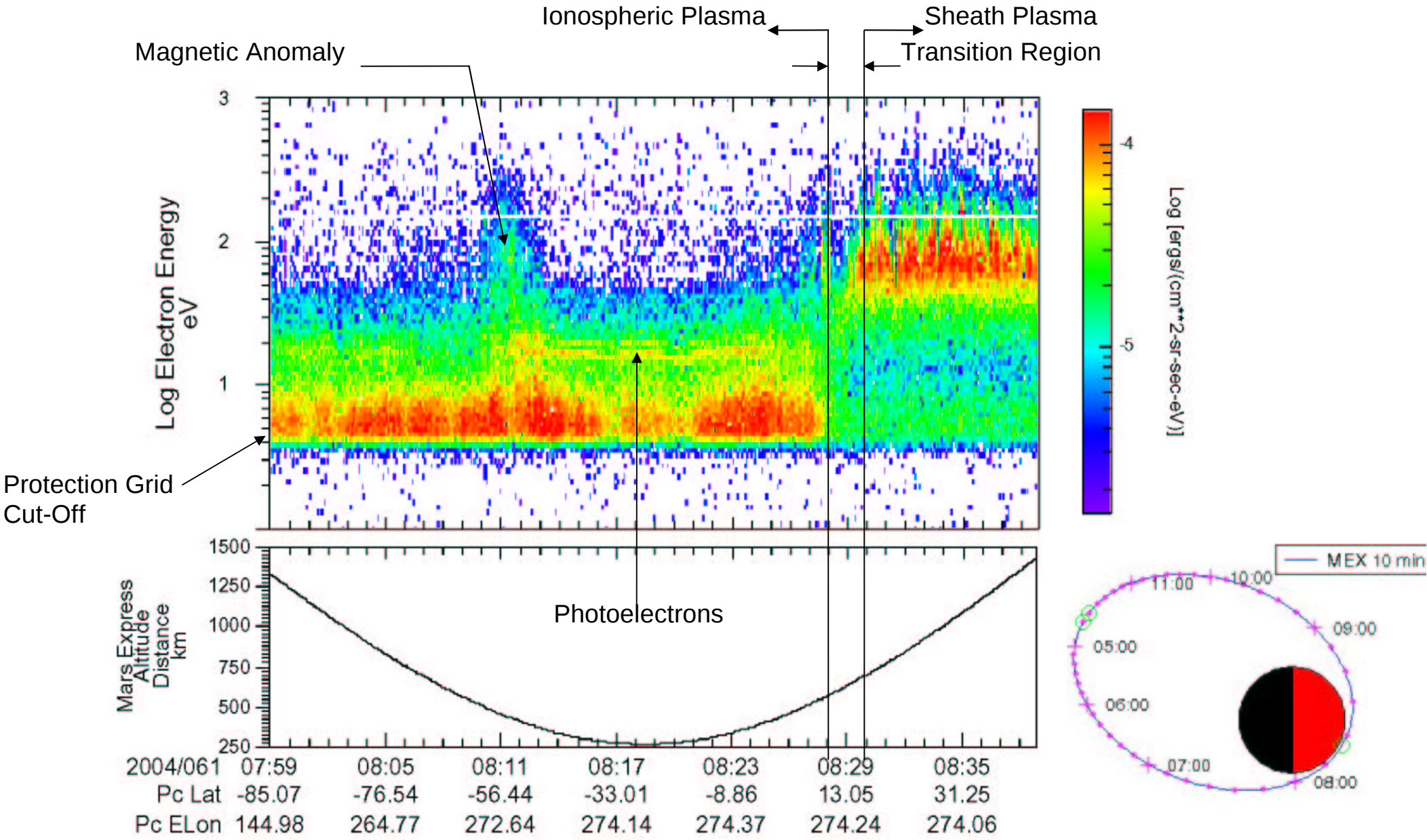
Figure 2


Mars Electron Fluxes (Integrated 0-180°)
Differential Number Flux (electrons/cm2/s/eV)
Energy (eV)
309 km
152 km
110 km
$h\nu_{304} + CO_2$
$e + CO_2(vib)$
^6C
^7N
^8O
10^{10}
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
1
10
100
1000

Contiguous Sampling Achievement



Electrons in the Mars Ionosphere



30.4 nm Photoionization of Carbon Dioxide

$$CO_2 + h\nu \longrightarrow CO_2^+ + e^- \begin{cases} X^2\Pi_g \text{ ionization potential } 13.8 \text{ eV} \longrightarrow 27.0 \text{ eV electron} \\ A^2\Pi_u \text{ ionization potential } 17.7 \text{ eV} \longrightarrow 23.1 \text{ eV electron} \\ B^2\Sigma_u^+ \text{ ionization potential } 18.1 \text{ eV} \longrightarrow 22.7 \text{ eV electron} \\ C^2\Sigma_g^+ \text{ ionization potential } 19.4 \text{ eV} \longrightarrow 21.4 \text{ eV electron} \end{cases}$$

TA006195_AGU

[Padial et al., 1981]

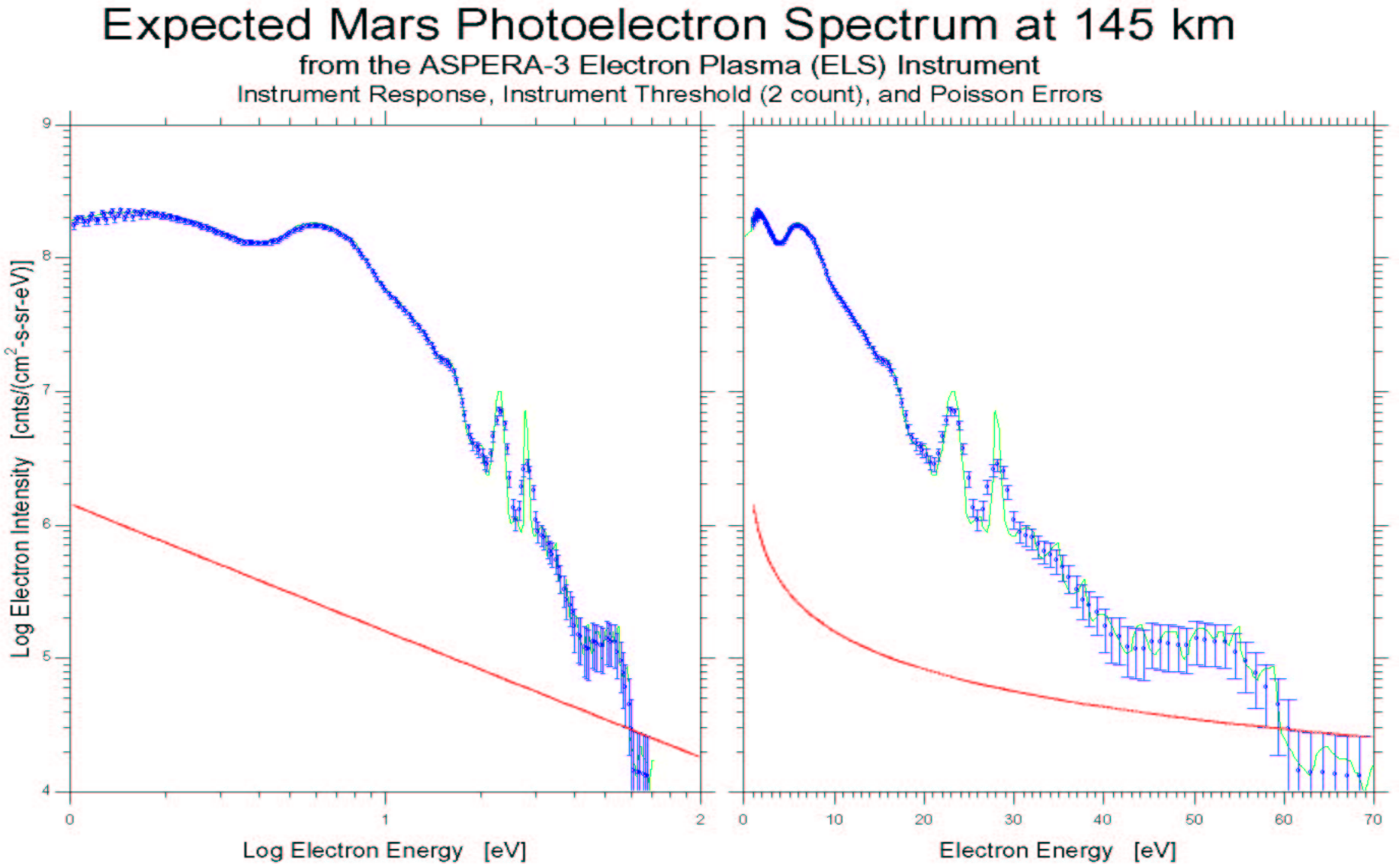
30.4 nm Photoionization of Atomic Oxygen

$$O + h\nu \longrightarrow O^{+} + e^{-} \begin{cases} {}^{4}S \text{ ionization potential } 13.62 \text{ eV} \longrightarrow 27.16 \text{ eV electron} \\ {}^{2}D \text{ ionization potential } 17.10 \text{ eV} \longrightarrow 23.68 \text{ eV electron} \\ {}^{2}P \text{ ionization potential } 18.50 \text{ eV} \longrightarrow 22.28 \text{ eV electron} \end{cases}$$

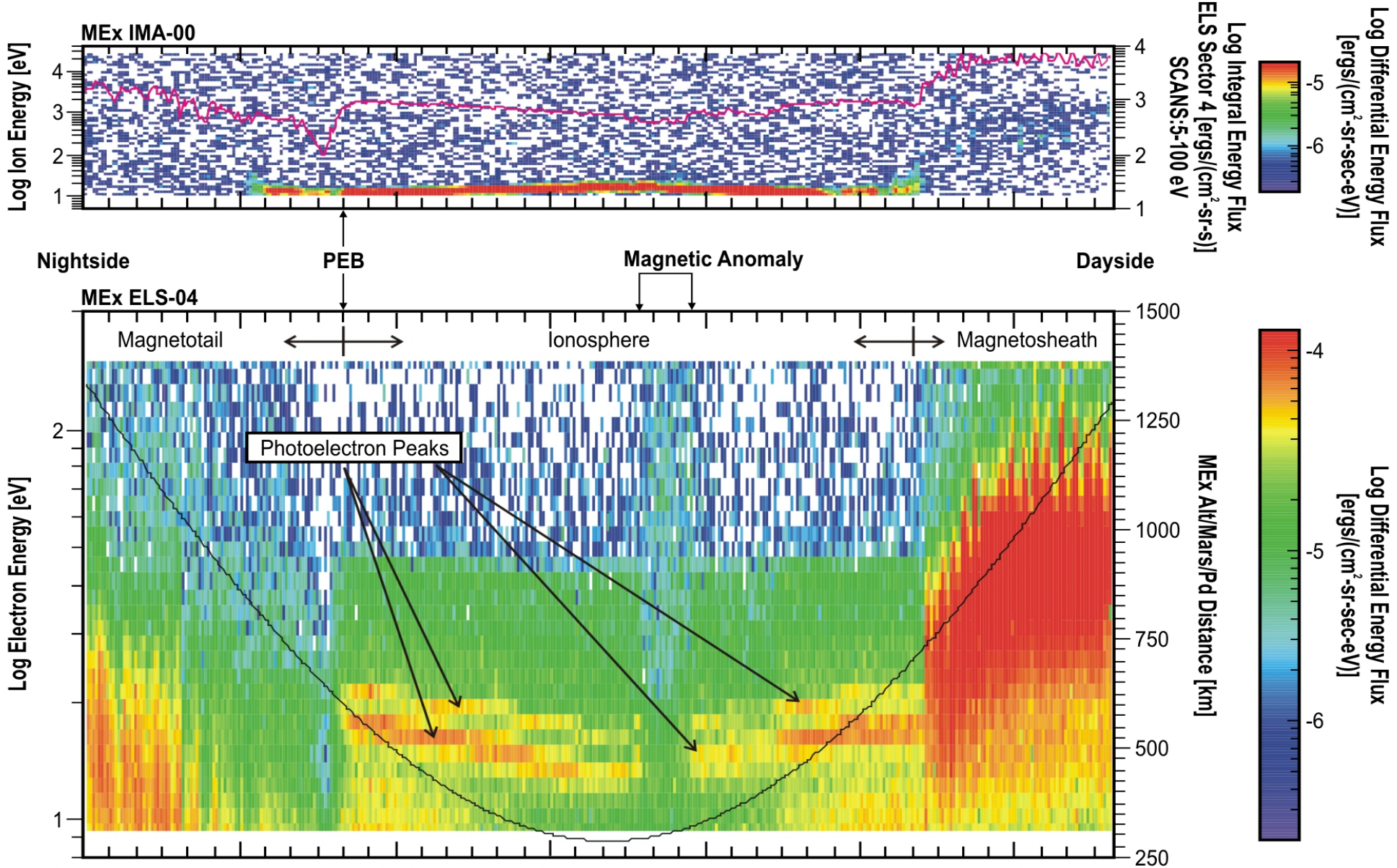
TA006169_AGU

[Mantas and Hanson, 1979]

Oversampling Spectral Resolution Achievement



19 June 2007 Ionosphere Plasma

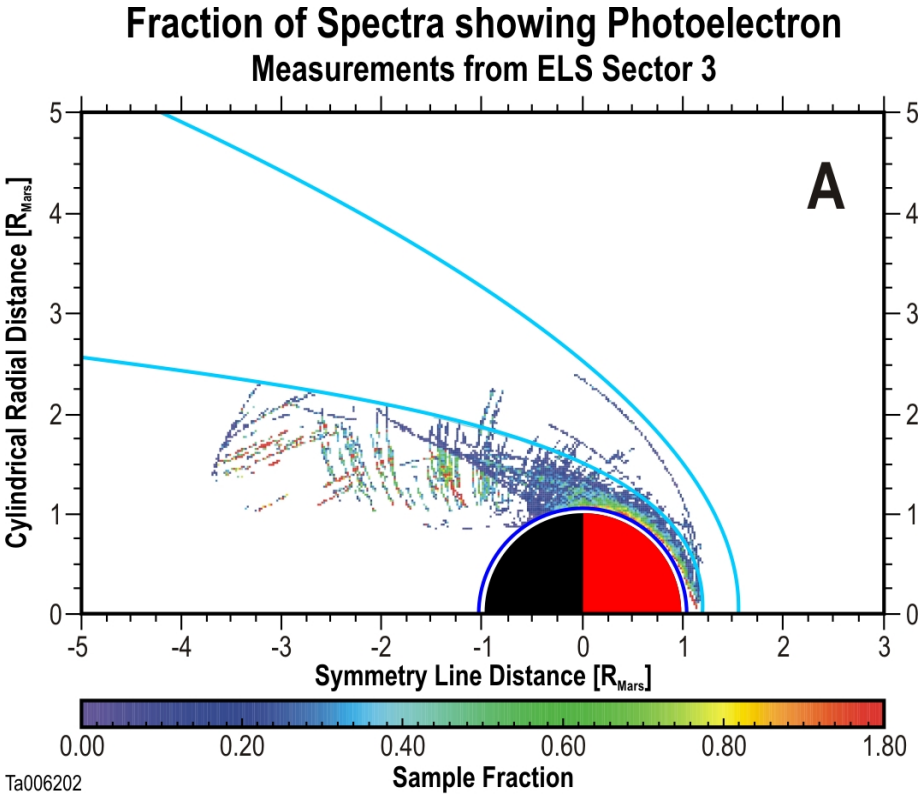


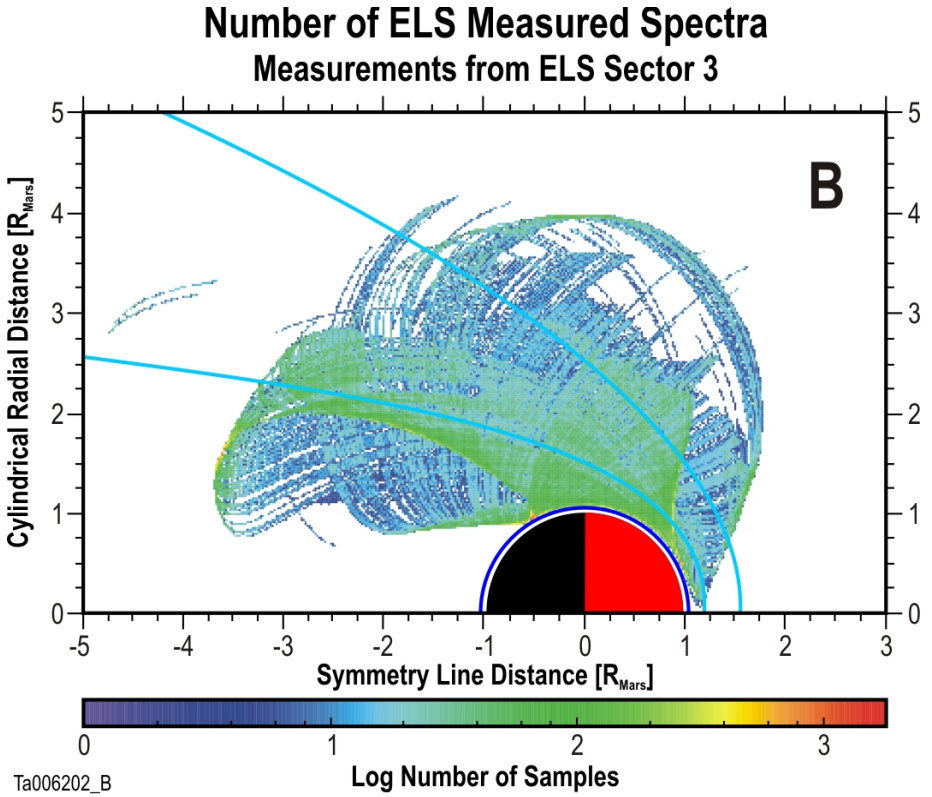
2007/170 15:25	15:31	15:37	15:43	15:49	15:55	16:01
SZA (deg) 104.64	88.70	69.20	46.78	24.09	9.87	21.08
PdLat (deg) -49.34	-65.40	-84.24	-71.79	-48.21	-26.08	-7.25
PdLon (deg) 80.84	82.73	108.60	242.64	247.51	248.10	247.83
SolTime (hr) 1.59	7.20	11.96	12.38	12.55	12.66	12.66
SolLat (deg) -73.98	-85.77	-69.19	-46.50	-22.73	-0.67	17.99

Ta006203

2004 Distinct Photoelectron Statistics

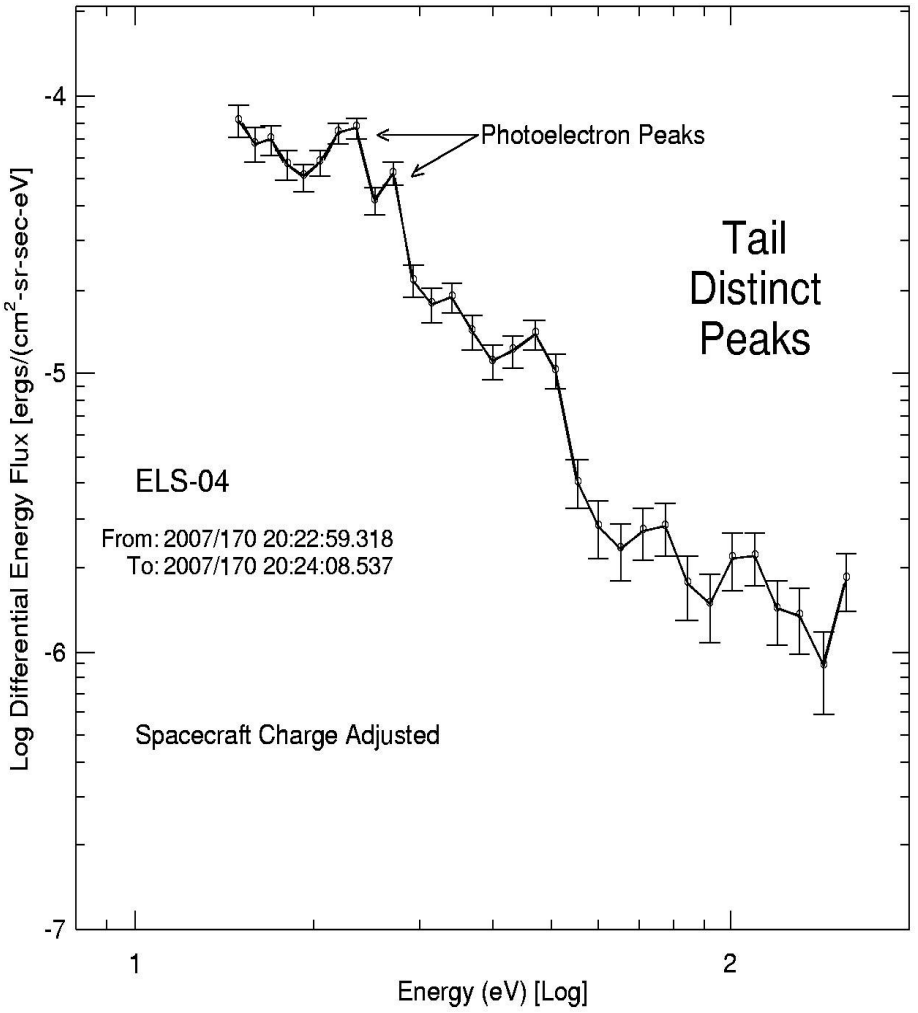
Jan 05, 2004 – Jan 25, 2005

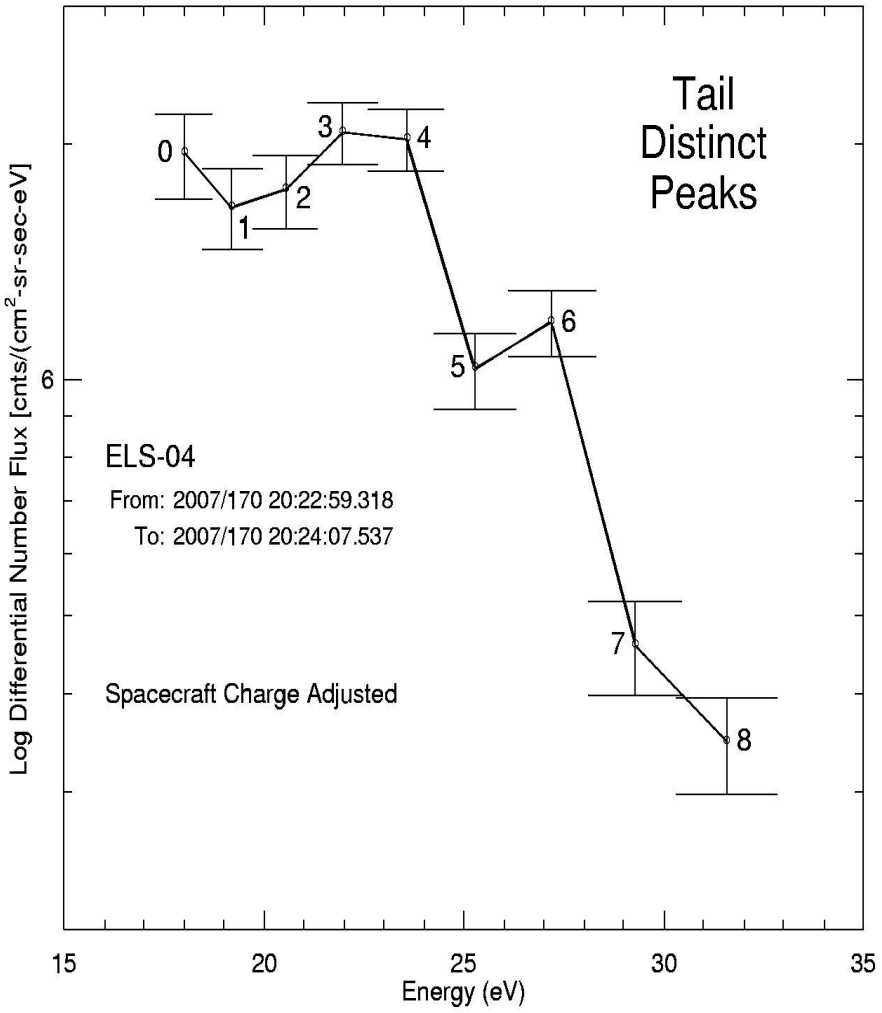




- 81,575 measured spectra less than 1.5 R_{Mars} and below average MPB position
- 7,331 Photoelectron spectra less than 1.5 R_{Mars} and below average MPB position
- ELS measured distinct photoelectron spectra 9% of the time

Electron Flux Integration Details





Escaping Electron: 5,74 x 10^6 electrons/(cm^2 s sr)

Uncertainty: 1.26 x 10^{26} electrons/(cm^2 s sr)

Photoelectron Escape Rate

Electron Outflow

= Electron Flux * Angular Flow * Escape Area * Yearly Measured Fraction

= 5.74×10^{6} * 0.478 * 1.16×10^{18} * 0.09

= $2.85 \pm 1.53 \times 10^{23}$ electrons/s

2004 Electron loss = 15 ± 8 Mmole

Acknowledgement: NASA Contract NASW-00003

Conclusion

The ASPERA program at SwRI has been highly successful in achieving hardware, software, and science goals.

SwRI has made this FIRST NASA Discovery Program Mission of Opportunity a success.

Thanks to all who have contributed to and continue to contribute to the ASPERA program.

Acknowledgement: NASA Contract NASW-00003